DISCOVERY

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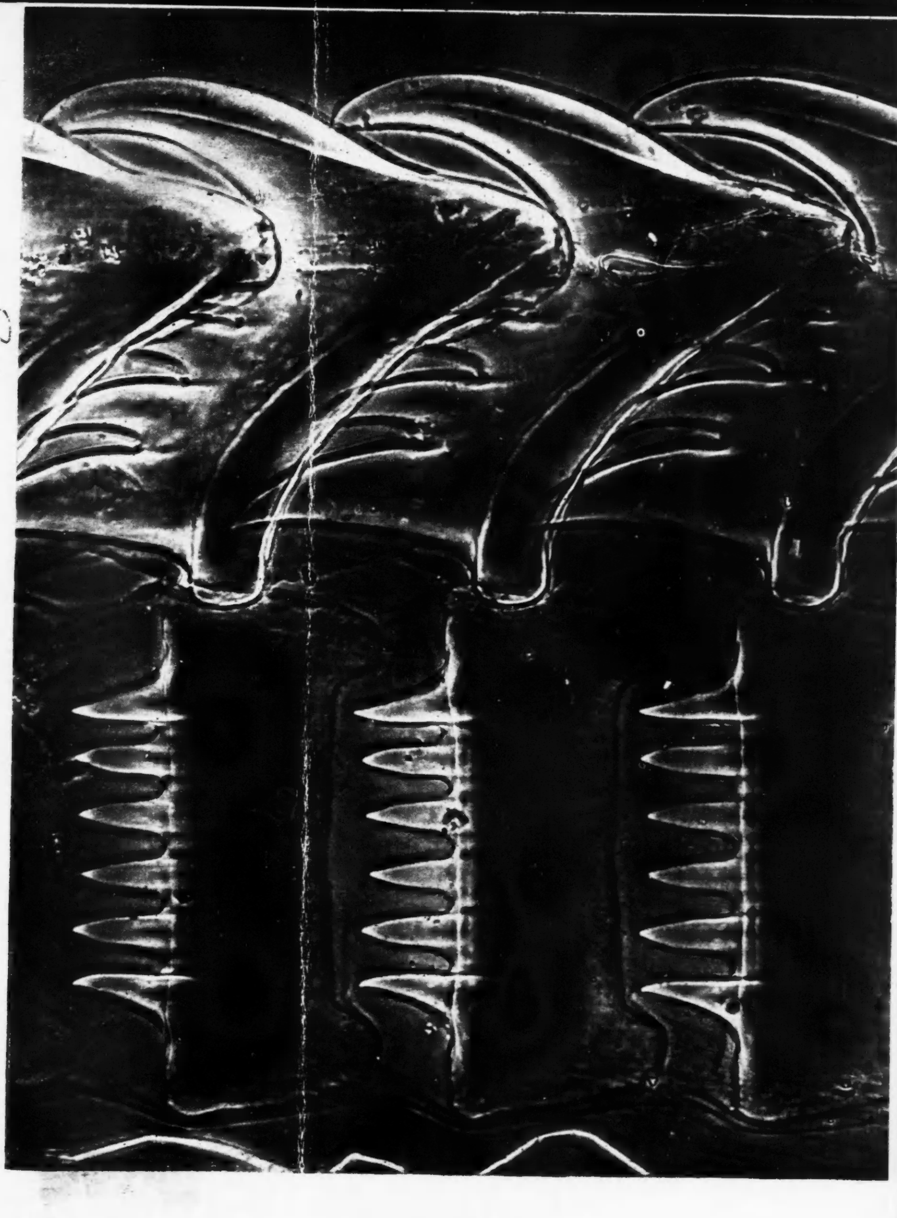

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The Progress of Science

Keeping Warm and Going

THE end of the 1951 was exceptionally mild. Cattle were still grazing in December, and just as well, with the poor hay-harvest. There were no power-cuts, and there was an exceptional 'bull' week with 4·9 million tons from the pits and, more surprisingly, 4·3 million in the week following. These figures are the only encouraging ones in the permanent fuel and power crisis as indicative of what can be done. The common attitude which has been discussed before in this journal is to emphasise that economies in consumption can be made. The standard statement is that an expenditure of £50 million in modernising industrial and domestic grates would save 20 million tons of coal a year. But, so far, no progress can be seen in this direction.

During 1950 the inland consumption of coal in Great Britain was 202·5 million tons, divided as follows:

	Thousand tons	*Percentage*
Gas	26,226	12·9
Electricity	32,911	16·3
Water	346	0·2
Railways	14,539	7·2
Coke Ovens	22,498	11·1
Industrial 'A' Consumers	44,635	22·0
Domestic—Miners' Coal	5,025	2·5
Merchants' disposal of House Coal	30,190	14·9
Anthracite and Boiler Fuel	2,267	1·1
Collieries	10,716	5·3
Miscellaneous	13,108	6·5

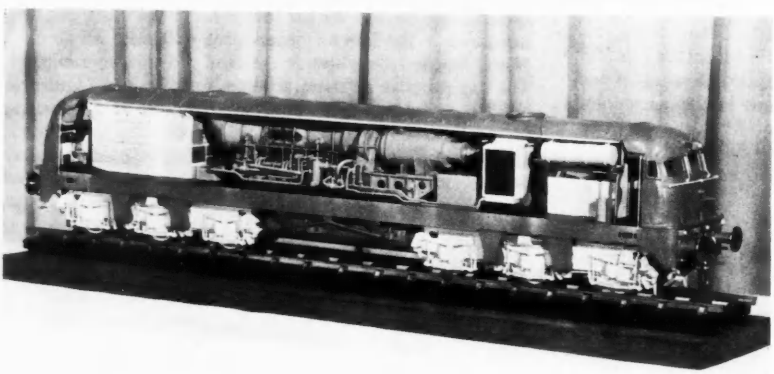
No proposals are put forward for increasing the efficiency of the gas industry which is recognised as high. Electricity is a fair target; with a 25% efficiency it appears to offer great scope. It is a combination of a high thermal efficiency in combustion, nearly 90 per cent in the best installations, with a thermodynamic efficiency of conversion to power around 30 per cent, representing the limits of temperature for the material used. The usual suggestions for economy are to use the latent heat of the steam rejected from the turbines for district-heating schemes or the power in heat pumps which turn Carnot's cycle upside down. We get this in many technical publications and in the latest Conservative pamphlet *Make Coal Work Harder*. Nowhere is the case proved economically. The capital cost of these schemes is high and requires a good time to write off. The same amount of condensing plant and cooling towers has to be provided while more generating capacity is needed to produce the same power on a worse cycle, since the steam can no longer be degraded from 900° F. to 100° F. but to about 200°–220° F. With power, the most critically deficient item in our economy, it is impossible to see how these schemes can be considered. This also applies to the other possibility, which is seldom looked at, to pass out steam at a pressure high enough for industrial process use.

This criticism can also be made of the suggestions to put improved domestic fires into houses. The only houses with a reasonable degree of comfort are those receiving miners' concessionary coal. Improved efficiency in burning the small amounts allowed to other domestic users would be absorbed in increasing comfort to tolerable levels. The only possible help might come from a reduction in the use of electric space and water heating. The much-abused electric fire bears comparison with solid fuel heating when the overall thermal efficiencies are put side by side and the ease of switching on for short periods set against the total fuel required to start a fire and build it up. What is incomprehensible is that electricity for domestic heating is sold below cost.

According to the Conservative pamphlet, the best possibilities for economy are offered by industry where 'the thermal efficiency of the coal used is about 20 per cent'. This is a most misleading half-truth. It may apply where steam generation is used only for prime movers, but the bulk goes in processes. Combined power and process steam schemes are possible only in exceptional factories. Economy is possible by careful control of firing, excess air, etc., and the Ministry of Fuel and Power teams already tackle this. It is difficult to guarantee that improvements

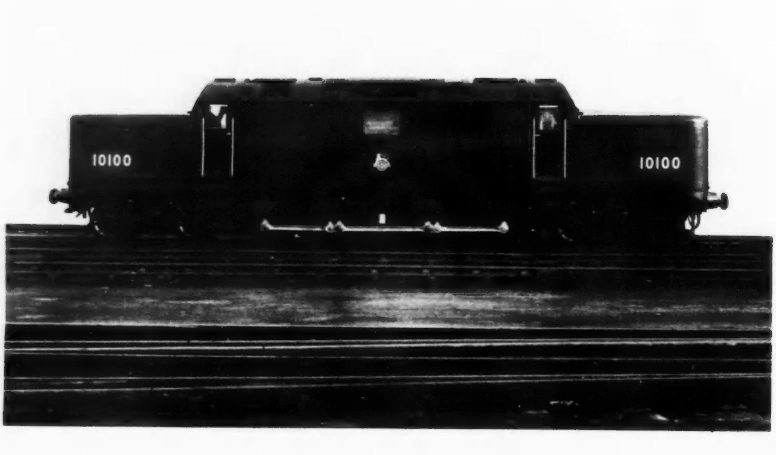
THE FIRST BRITISH-BUILT GAS TURBINE LOCOMOTIVE No. 18100

General view of Locomotive manufactured for British Railways by Metropolitan-Vickers Electrical Company Ltd.



Model of the Metropolitan-Vickers Locomotive: cut-away to show layout of equipment.

(*British Railways, Western Region, Photographs.*)



4-8-4 Diesel Mechanical Locomotive No. 10100. Built at Derby Works (London Midland Region), 1951, to the design of Mr. H. G. Ivatt in collaboration with Fell Development Ltd. and Ricardo and Co.; 200 h.p. unit; max. speed, 78 m.p.h.

will be kept up because even indicators which seem simple, such as CO_2 meters, require continual maintenance.

The demand for coal by coke ovens is likely to increase as the proportion of scrap in steel manufacture drops. The economies possible through gas ring-mains and new coke-oven gas holders for week-end makes have already been made and the demand for steel can only rise as rearmament proceeds. The only victim left is the railways. They have the shakiest ground of all. The percentage efficiencies of locomotives are: Steam, 7; Gas Turbine, 17; Electric, 17; Diesel, 30.

There were two British Diesel locomotives running in the summer of 1951 and one with gas-turbine drive has just gone into service. In the U.S.A., 2396 new locomotives were built in 1950, and of these 2372 were Diesels. Fifty per cent of all American traffic is now hauled by Diesels. The case for conversion is overwhelming except for the strategic need to use home-produced fuel.

It may seem a hard conclusion that technical means cannot reduce the consumption of coal at present. More comfort, more power and steam for production are possible but not a net saving as so many tons which might be made available for export. To produce a surplus requires political decisions and the fruition of the N.C.B. programme of reorganisation. 1951 gave six million tons more output than 1950 and it is to the pits we must look for a surplus.

Synthetic Rubber for Britain?

THE latest *ballon d'essai* is made of synthetic rubber. Sir Clive Ballieu, chairman of the Dunlop Rubber Company, has declared that it is timely for the "Government, the chemical engineering industry and the consuming industry to consider afresh what appropriate action can be taken to establish the manufacture of synthetic rubber in this country". The Dunlop Rubber Company would "continue to co-operate in practical measures". The *Economist* suggests that Dunlop will have to take a leading part in setting up and in operating whatever synthetic rubber plants may be built.

This does not seem to be a necessity from technical considerations and there would be enough contending interests without all the rubber companies joining in to keep one from having a monopoly. There are a number of different synthetic rubbers to choose from but 'cold GR-S' would probably be the material of choice. This is a co-polymer of butadiene and styrene, the polymerisation being carried out at comparatively low temperature, 41° F. The source of butadiene is ethyl alcohol via some such route as ethyl alcohol→acetaldehyde→acetaldol→butylene glycol→butadiene, or the dehydrogenation of butane from oil cracking. The alcohol is produced either by the fermentation of waste carbohydrate such as molasses or by the hydration of ethylene produced in oil or gas cracking.

Clearly the first opposition can be expected from the producers of natural rubber in Malaya. The difficulty in realising a stable political position in Malaya is now so deep-seated that the establishment of a synthetic rubber industry as an insurance policy is practically important. The other contenders are the potential operators.

The name of Esso Petroleum Co. has been mentioned and finds more support after the achievement in constructing the new Fawley refinery. They would be expected to mobilise the necessary American technical assistance and possibly American capital to finance the construction of the plant. Preliminary plans have already been made by this company and are believed to have progressed to the stage where Foster-Wheeler Ltd., the American chemical engineering contractors for Fawley, are prepared to quote for the construction. Spheres for butane storage under pressure already form part of the Fawley installation.

The idea of any firm, native or foreign, entering into the alcohol-manufacturing business is anathema to the Distillers' Company. The synthetic balloon is set on its course with the publication of the report in the *Glasgow Herald* that synthetic rubber production is being considered by the Scottish Development Council. The site of choice would be Grangemouth where a petroleum chemicals plant has been jointly constructed by the Distillers and Anglo-Iranian Oil Companies. This plant has the advantage of already including a styrene unit so that experience of producing one raw material would be available.

Styrene is made by dehydrogenating ethylbenzene produced from benzene and ethylene. If ethylene is a starting point for butadiene, another stage is also realised.

In the United States, the rubber programme is hampered by shortage of benzene. In this country there is a latent reserve in the gallonage which goes to produce motor benzole. Some is already exported to the U.S.A. but more could be available, particularly when the new oil catalytic-crackers are producing higher octane motor spirit and reducing the demand for motor benzole to bring the petrol from Middle East sources up to a reasonable level. The requirements for an economic size synthetic rubber plant would be 5–10 million gallons per annum.

The other types of synthetic rubber might also be attractive to some producers. Butyl rubber, from isobutylene and butadiene, is attractive for making inner tubes. The isobutylene production of the oil plants would, however, be preferentially diverted to iso-octane production for aircraft fuel. The manufacture of Perbunan has been revived in Germany at Leverkusen where acrylonitrile is made and reacted with butadiene from Hüls. This process might be attractive to I.C.I. to develop at Wilton where a new oil-cracking plant is under construction. I.C.I. could also expand their production of neoprene, a polymer of 2-chlorbutadiene which has excellent resistance to attack by oil and is also non-inflammable.

Our own view is that reliance should be placed on the capacity of British firms to produce the necessary styrene and butadiene to make GR-S. Owing to the lack of adequate chemical engineering facilities here, the Grangemouth plant has been constructed by the American firm E. B. Badger & Co. A wholly British plant has been designed from scratch by Petrochemicals at Manchester but has had delays in getting away. This should not discourage extensions of the Grangemouth project, which could give the raw materials for polymerisation. This stage is the difficult one, for which licensing of American

patents would be needed. The polymerisation is carried out in emulsion and results in the production of a rubber 'crumb' which is suitable for processing by the rubber manufacturers. They already possess the manufacturing technique worked out during the war when synthetic rubber was imported from the United States.

Once the design and operating requirements have been worked out here for synthetic rubber plants, strategic needs would indicate that further extensions should take place in Canada near the source of oil. This would involve an additional step in producing synthetic benzene as there is a shortage on the American continent. The American view might be in favour of developments, if at all, in Canada alone but to bypass the prior construction in this country would seriously damage our economic and technical potential.

Freeth and the Phase Rule

MATHEMATICAL statements with the most far-reaching effects are often distinguished by their elegance and simplicity. Einstein's equation of energy and mass, $E=mc^2$, is one whose explosive possibilities have now been realised. Another is Gibbs' Phase Rule, $C-P+2=F$, where C stands for *components*, P for *phases* and F for *degrees of freedom*. The example used most often to illustrate this rule is the triple-point for water, at which ice, water and water-vapour exist together. These are three phases, solid, liquid and gas: the substance H_2O is the one component and the system is then declared to have $1-3+2=0$ degrees of freedom. It is impossible to change the pressure or the temperature without one of the phases disappearing. If the temperature is lowered, the water disappears. If the pressure is raised, the ice disappears.

J. Willard Gibbs had the habit of recording revolutionary discoveries in the most obscure manner and the most obscure journals. He was Professor of Mathematical Physics at Yale University and published the Phase Rule in the *Transactions of the Connecticut Academy*, 1876. It remained there unnoticed, while van't Hoff developed independently his studies in chemical equilibria from 1881 onwards, until disinterred by Roozeboom in 1887 at the suggestion of van der Waals. The first important use of the rule was the study of the Strassfurt salt beds by van't Hoff in 1896 to determine how these complex bands of potassium, sodium and magnesium salts were laid down. The credit for the basic development of this branch of physical chemistry is due to Dutchmen.

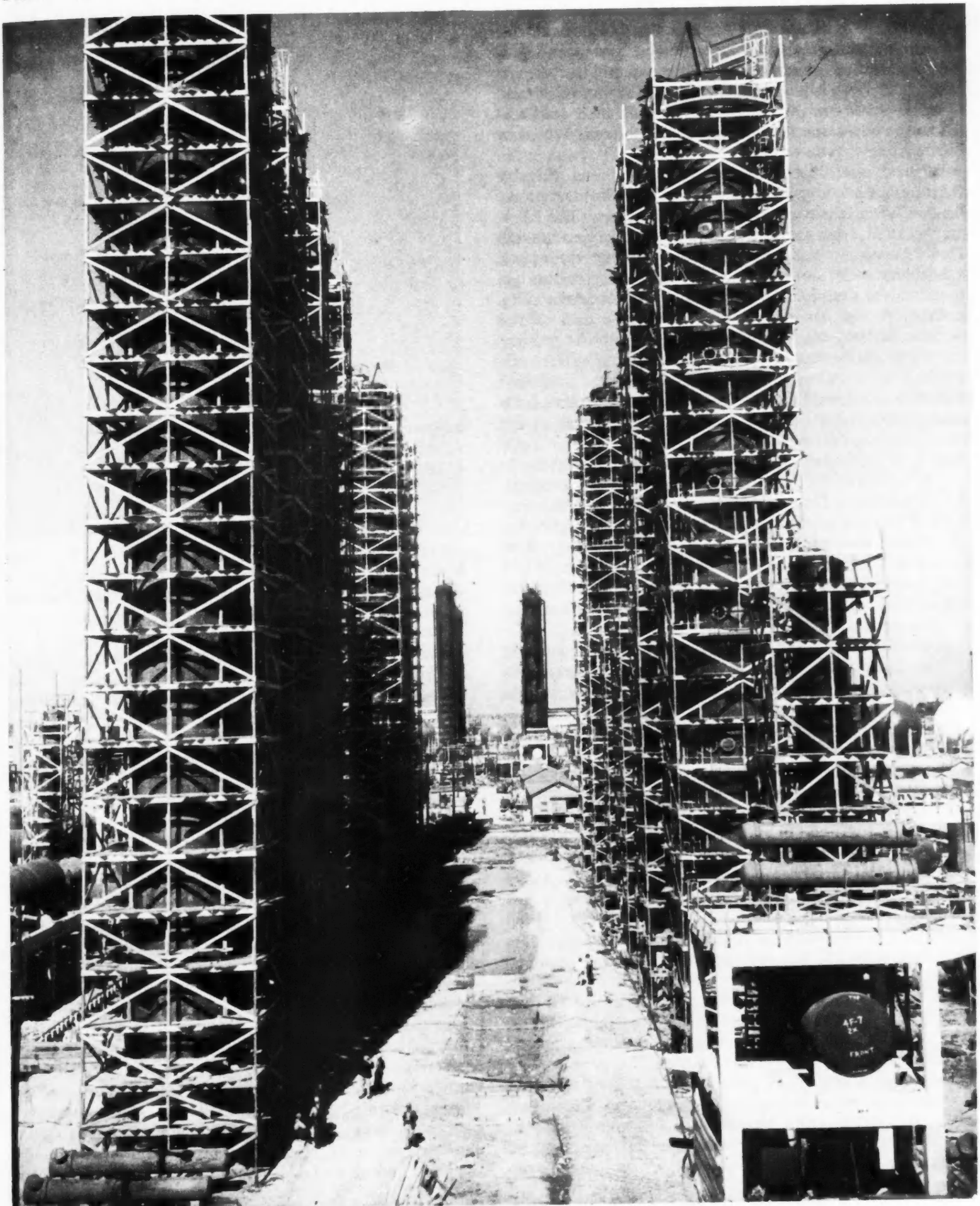
The man who put teeth in it was F. A. Freeth. He is a legendary figure and some of the stories about him should be written down. His background is entirely martial: great-grandfather, General Sir James Freeth, Quartermaster-General; grandfather, Major-General, R.E.; father, master-mariner and R.N.R.; himself, Major; his son, Lieutenant-Commander, R.N.V.R. This sport from military stock graduated from Liverpool and remains as typically liverpudlian as that other great man, the late Tommy Handley. He joined Brunner Mond's new research department at Winnington in 1907 and arrived at his Northwich lodgings accompanied by a porter pushing a handcart piled with scientific apparatus. He was given a free hand, and in his own words "shot up like a cork". The salt of Northwich and the ammonia-soda process at Winnington propelled him into the study of the phase rule. The studies did not remain academic.

He was recalled from field service near Ypres in 1915 for important duties connected with munitions. At that time this country was desperately short of high explosive; when it was found that T.N.T. could be used with equal effect in conjunction with four times its weight of ammonium nitrate, Freeth worked out a process, British Patent (1917) 126,678, to react ammonium sulphate with sodium nitrate (Chile saltpetre). It was triumphantly successful and, in the words of Professor Donnan, "he took the phase rule of Gibbs into the very cannon's mouth". This work earned him the O.B.E., and this tribute from Lord Melchett in 1928: "During the war this country was in a very serious condition in regard to high explosives. An explosive which was practically unused by us in the early days of the war became the chief explosive of ourselves and our allies. It was a question of turning out T.N.T. and methods had to be devised in which tonnage replaced pounds. In the manufacture of ammonium nitrate no method had previously been known of producing it in hundreds of tons. All we could find were the textbooks which said the various methods had been tried but that they had been unsuccessful. We had on our staff an eminent and distinguished scientist in the person of Captain Freeth. He applied the theoretical work of Willard Gibbs to the practical problem of production on a larger scale and helped us to work out a process to produce thousands of tons and, I can say without exaggeration, saved the allied forces in the field."

After that war, Freeth visited Holland and made a great impression. The University of Leiden invited him to present a thesis for which they gave him their D.Sc. It included an ingenious cyclical process for separating ammonium perchlorate from ammonium sulphate in solution, and another for separating ammonium sulphate and sodium sulphate which form double salts. His D.Sc. was quickly followed by election to the Fellowship of the Royal Society.

It was the study of reciprocal salt pairs which showed off his virtuosity. These are systems of four components such as ammonium sulphate and sodium nitrate, each ion in solution being a component. The process used by I.C.I. at Billingham to produce ammonium sulphate by the double decomposition of calcium sulphate (anhydrite) and ammonium carbonate is another example of Freeth's inspiration. The saving of sulphuric acid and sulphur imports by this process has been a national asset for many years.

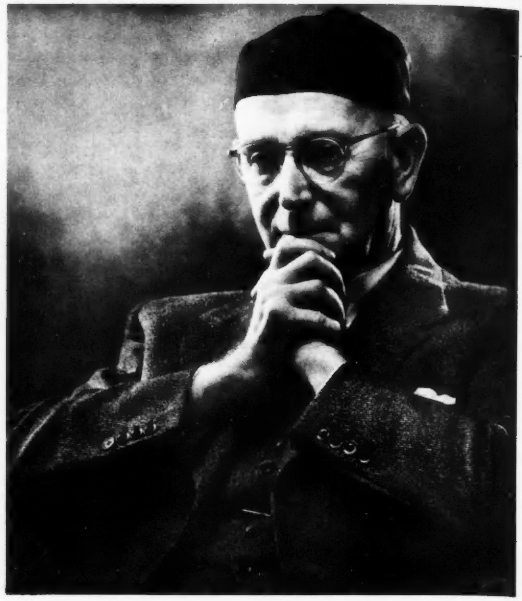
Dr. Freeth retires from I.C.I. this month. Early in his career with Brunner Mond he engaged scientific staff who have subsequently become the present directors of I.C.I., and he finishes in I.C.I. Central Staff Department. His influence has been widespread and has recently been brought to bear on the advancement of chemical engineering. The discovery of the potash deposits in Yorkshire during the D'Arcy Exploration Co.'s boring for oil showed a typical reaction from him. With Sir Thomas Merton of the Royal Society he went to see Sir Stafford Cripps, then Chancellor of the Exchequer, to point out the great value to Britain of this discovery. Cripps welcomed the suggestion that I.C.I. should look into the possibilities. The Ministry of Fuel and Power, however, claimed the discovery



SYNTHETIC RUBBER PLANTS like those erected in the U.S.A. are advocated for Britain. This photograph shows the tall processing towers in the world's largest butadiene projects at Port Neches, Texas, which line a thoroughfare called Butadiene Boulevard. In the foreground is the South Unit, and in the distance the North. The latter is designed to produce butadiene, chief ingredient of synthetic rubber, from refinery gases supplied by five American companies which operate the plant for the U.S. Government without profit or management fee.

as arising from oil exploration and announced they would send a team to Searles Lake in America to get the 'know-how' on extraction of potash. This particular deposit had been investigated and worked out by Freeth nearly thirty years earlier. His remark was that the Ministry of Fuel and Power would bore through twenty feet of solid gold and throw the cores on one side, if they did not show coal or oil.

When a new Honours List comes out, and Freeth's O.B.E. is set in comparison with other "political and public services", the scale of values seems wrong. The I.C.I. magazine says his favourite quotation is Ecclesiastes IX, 11:—"I returned, and saw under the sun that the race is not to the swift, nor the battle to the strong, neither yet bread to the wise, nor yet riches to men of understanding, nor yet favour to men of skill; but time and chance happeneth to them all." It might be added that "a prophet is not without honour, save in his own country". The good wishes of this journal go to Dr. Freeth with the hope that his retirement from I.C.I. will allow him to find other fields to conquer.



DR. F. A. FREETH

Nuclei near Absolute Zero

A LETTER to the November 3rd, 1951 issue of *Nature* reported work done on the alignment of nuclei in the Clarendon Laboratory, Oxford. This was the result of collaboration between the low temperature department and the nuclear physics department, and the following account is based on information provided by the team of research workers who carried out the experiment.

One of the frontiers of research in physics lies in the field of low temperatures. Lowering the temperature of a system decreases the disordered motion of the constituent atoms and molecules, and hence produces a greater degree or order in the molecular arrangement. Well-known examples are: liquefaction and solidification; in each case the random translational motion of the molecules is decreased. A more abstruse case is provided by the magnetic dipoles in a paramagnetic substance. At high temperatures these point indiscriminately in all directions, but at low temperatures they tend all to point in one or two directions —clearly an arrangement of greater order. That all systems finally pass into a state of perfect order at sufficiently low temperatures is a somewhat abbreviated statement of the Third Law of Thermodynamics. Naturally the temperature at which ordering sets in will be lower in proportion as the interaction forces responsible for the ordering become smaller. If the magnetic dipoles are associated with electrons, then ordering generally sets in at about 0·1 to 0·01° K. The nuclei of some atoms also possess magnetic moments, but these are about a thousand times smaller than those of the electrons. So we may expect that it will take very low temperatures indeed to create order in the orientations of the nuclear magnetic moments. It has been calculated that this order will set in spontaneously through magnetic interaction forces between the nuclei in the temperature region of 10^{-5} to 10^{-6}° K.

Since the degree of order increases as the temperature is reduced, it follows that to produce low temperatures we need some mechanism for producing greater order by external means. For instance, it is well known that if a magnetic field is applied to a substance with electronic magnetic dipoles at about 1° K., the dipoles are pulled round parallel to the field. The order is very much increased and heat is expelled from the substance. If the field is then removed under conditions in which the heat cannot return to the substance, the temperature falls until the same degree of order is attained by the action of internal forces—about 0·01° K. The possibility of making similar experiments with nuclear magnets leading to temperatures of the order of 10^{-5}° K. has been discussed in some detail by Simon in 1939. At such temperatures the nuclear magnets will be 'lined up' by their mutual interaction.

From that time onwards preparations have been made at the Clarendon Laboratory under the general direction of Professor Simon and Dr. Kurti who, since experiments with oriented nuclei must obviously be of great interest to nuclear physics, were later joined by Dr. Halban for work in this field. Because nuclear magnetic moments are very small, very large external magnetic fields must be employed even when starting at very low temperatures. For example, a field of 100,000 gauss would be necessary at 0·01° K. to lead to a reduction of the entropy (which is a measure of the degree of order) by about 25%. A 2000 Kilowatt generator has been installed at the Clarendon and solenoids for 70 Kilogauss have been built. While this 'external field method' is applicable to all nuclei possessing a magnetic moment, and while it alone would lead to a way of lowering temperatures by another very big step—and it is the only way we can foresee at the moment—it is not an easy one from the experimental point of view, particularly because of the difficulty of heat transfer at these low temperatures. The preparatory experiments in the Clarendon Laboratory have shown, however, that one may expect positive results within, say, the next year.

Meanwhile the Clarendon group have been occupying themselves with other methods which have recently been suggested and which although not of general applicability can nevertheless lead to the alignment of nuclei in some special systems. The preparations for the 'external field method' have been of considerable help in this respect.

Prof. Gorter of Leiden and Dr. Rose of the Oak Ridge National Laboratory, independently suggested that it might be possible to use the very strong field which the electrons produce at the nucleus of a paramagnetic atom to align the nuclei. It would then be sufficient to orient the electrons and this could be attained with very modest external magnetic fields at temperatures of the order of 0·01°K. Prof. Pound of Harvard pointed out that one could use instead the interaction between electric field gradients in a crystal and the electric quadrupole moment of the nucleus, which would have the effect of lining up the nuclei about one of the crystal axes. Finally, Dr. Bleaney, of the Clarendon Laboratory, pointed out that in certain paramagnetic substances, the magnetic interaction between the electric and nuclear magnets is strongly directional, so that in the absence of an external magnetic field the nuclei would be aligned along a crystal axis, as in Pound's method.

The Leiden workers had been experimenting since 1949 with the Gorter-Rose method without obtaining conclusive results. The Clarendon group has understandably concentrated on Bleaney's method, particularly since Bleaney and his collaborators in the Clarendon Laboratory have carefully studied the properties of various paramagnetic salts, using the method of paramagnetic resonance. A salt was finally chosen with suitable properties containing the radioactive nucleus Co^{60} and the first experiments carried out in September 1951 by Daniels, Grace and Robinson were completely successful. Considerable alignment has been attained and this was proved by the fact that the γ radiation emitted was strongly anisotropic.

The substance used was a single crystal of (1% Co, 12% Cu, 78% Zn) $SO_4.Rb_2SO_4.6H_2O$. Some of the cobalt nuclei were replaced by the radioactive isotope Co^{60} and the γ rays emitted from its disintegration were counted by an array of Geiger counters mounted in different directions with respect to the crystal axes. The crystal was placed in a strong magnetic field at 1°K., when the electronic magnets were ordered, but not the nuclear magnets. On switching off the field with the crystal thermally isolated, the total order remains constant but is mostly transferred from the electronic magnets to the nuclear magnets. The temperature of the crystal fell to approximately 0·01°K. rising over a period of 5 to 10 minutes to 0·1°K. While the crystal was near the lower temperature the number of γ rays emitted in directions at right angles to the axis of alignment was substantially (up to 45%) greater than the number emitted in directions near to the axis of alignment, but as the crystal warmed up and thermal agitation destroyed the order the emission became isotropic. These results confirm the predictions of Spiers and Steenberg of the extent to which γ-ray emission should be greater at the nuclear equator than at the poles. They also show that the γ-ray emission, which in this particular nuclear transition precedes the γ rays, does not destroy the alignment. From the quantitative results it was possible to obtain a value for the nuclear magnetic moment of the radioactive nucleus Co^{60} which was previously unknown. Subsequently the Leiden workers succeeded in obtaining 12% anisotropy by essentially the same method also using radioactive cobalt.

The alignment of nuclei opens up new fields in nuclear physics. Radioactive nuclei are complex systems of mass and charge and the emission of electromagnetic radiation (γ rays) by these systems is in many ways similar to the emission of radio waves by an aerial. It is well known that the radiation from an aerial is strongest in certain directions depending on the form and dimensions of the aerial; similarly a nucleus emits γ rays preferentially in certain directions relative to its own axis. Observation of the angular distribution of the intensity of γ radiation gives information about the changes in the distribution of nuclear charge and matter involved in the emission.

The Clarendon group aims to extend this method to other nuclei and also to increase the accuracy of the measurements in order to allow quantitative conclusions to be drawn about the mechanism of the γ-ray emission. For this purpose it is desirable, and it should be possible, to determine the plane of polarisation of the γ radiation. If circular polarisation can be observed the sign of the magnetic moment of the radioactive nuclei could be determined. Apart from γ radiation some of the problems concerning the interaction of particles (protons, neutrons, etc.) when colliding with aligned nuclei could be studied.

These few indications of the programme of the Clarendon group, by no means exhaustive, will make it clear that the way to a new and fruitful field has been opened.

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The Gas Turbine in Industry

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THE gas turbine is not a particular engine, it is a system, and its application to industry is still in the early stages. In consequence, much has still to be learned about its capabilities, costs and economy; nevertheless, it is already plain that there exist many applications where the gas turbine can at the present time be employed with profit. There are now on order or being made in this country industrial gas-turbine sets with a capacity totalling over 200,000 h.p. The tendency of gas-turbine manufacturers is to adopt a cautious policy of applying the gas turbine where there is a completely obvious application without going to too many complications involving control, temperature and other problems. Thus, it will be possible to build up experience in regard to particular applications and, as technique improves, to lower cost. Then will come the less obvious applications and the more involved cycles. It is already known that by the use of fairly complex cycles, efficiencies of the order of 35–40 per cent could be achieved in straight power-producing installations. What the life, capital costs, operating costs will be to achieve these efficiencies is less accurately known. At the present time, however, gas-turbine installations are running with efficiencies varying from about 15 per cent to over 30 per cent depending on the complexity of the plant. The last time I obtained a cost estimate for a power generator I was quoted a price about two-thirds that of comparable steam plant.

It may be asked why an engine with an efficiency as low as 15 per cent can be tolerated. The answer is that such a set is very simple, its capital cost is low in comparison with, say, a steam-turbine plant, which is of great importance where the unit is acting as a standby to supply peak loads. Further, such a plant requires no water for its operation and this makes it doubly attractive in places where water supply is absent or difficult.

The gas turbine finds a field opening up in the use of waste heat. In many chemical and industrial processes heat is evolved and thrown away into the atmosphere. It is true that such waste heat could be used in a boiler and the steam generated turned into power or used in processes. This, however, involves the capital cost of a boiler working at high pressure and its many auxiliaries and the maintenance thereof, whereas in the gas-turbine waste-heat cycle no boiler is required or, alternatively, if an air heater is used, such an item works at comparatively low pressure and consequently low tube stresses, which may reduce the cost. It should be noted, however, that experience with air heaters is as yet very limited, and the question of costs still indeterminate.

Gas Turbine Systems

In Fig. 1 a simple gas-turbine waste-heat system is shown, using the inverted cycle. The hot waste gases enter the turbine at atmospheric pressure. Expansion occurs in the turbine and the gases lose heat. Thereafter, the gases are cooled and emerge at slightly above the water temperature;

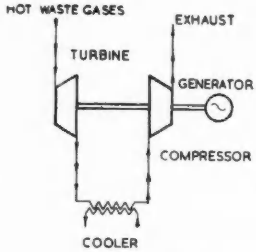


FIG. 1.

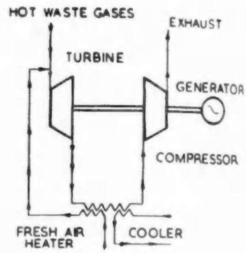


FIG. 2.

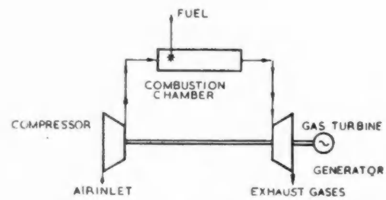


FIG. 3.

they are then compressed to atmospheric pressure and discharged. The essential simplicity and cheapness of such a cycle is obvious. The thermal efficiencies at the turbine couplings are of the order of 16 per cent with the turbine inlet temperatures in use at present, but the capital costs, maintenance and operating costs will be small. Some gain in efficiency and therefore output can be achieved on this cycle by the additional feature of a heat exchanger as shown in Fig. 2. Fresh air from the atmosphere passes through a heat exchanger deriving heat from the turbine exhaust. This heated air is then added to the waste gases entering the turbine. In this way the efficiency can be improved to some 18 per cent. At the same time the turbine inlet temperature is reduced, thus permitting the use of cheaper materials in the construction.

One of the big problems associated with gas turbines at the present time is that of coal burning. Distillate oil can be used successfully, as can crude or residual oil that is free from vanadium contamination or other reasonably clean fuels such as methane, natural gas, etc. With coal, however, we are presented with the difficulty of disposing of the ash content. If this is not done, then internal burning of coal produces dust and ashes that can have a serious erosive effect on the turbine blades. Steps are being taken to deal with this problem and no doubt reasonably successful solutions will appear in due course.

The alternative to direct coal burning is to heat the air supply to the turbine indirectly in an air heater. What then

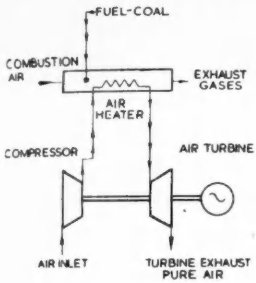


FIG. 4.

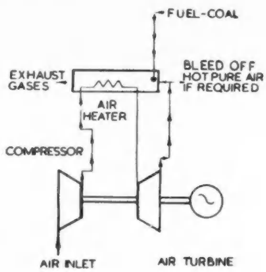


FIG. 5.

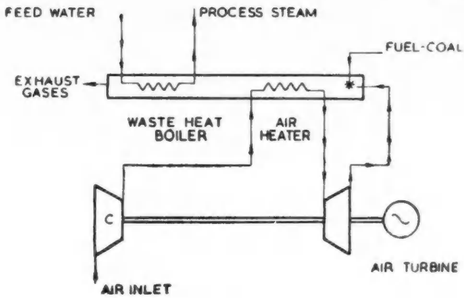


FIG. 6.

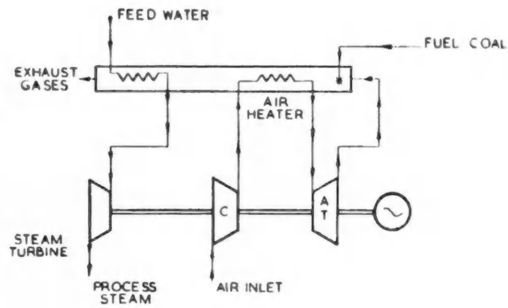


FIG. 7.

does this involve? Perhaps, before answering this question, it would be as well to consider the simple gas-turbine cycle.

Fig. 3 shows the basic essentials of a gas turbine. The air drawn in by the compressor is compressed, then heated by fuel burning directly in it. With light oil fuel or gaseous fuel this presents no difficulty, as witness the many thousands of gas-turbine aero-engines that have been made and also the growing number of successful industrial gas-turbine sets burning these fuels. After the compressed air has been heated it is expanded through a turbine. This turbine drives the compressor and the surplus power is put to useful purpose. The efficiency of such a cycle depends largely on the two factors of pressure ratio in the compressor and turbine inlet temperature.

It will be seen from Fig. 3 that, to develop the full efficiency of such a cycle, fairly large compressor pressure ratios are required and the peak efficiency is of the order of 16 per cent. This efficiency is not very high, but machines built on this basic cycle can find a niche for themselves as was pointed out earlier. With coal as our fuel, however, we must make modifications to the cycle. The simplest modification that we can make is to burn the coal outside the cycle in a furnace and heat up the compressed air of the gas turbine in tubes situated in the hot gases as shown in Fig. 4. Thus, instead of a combustion chamber situated directly in the gas-turbine fluid stream, we have an air heater or, as we may call it, an air boiler. Unfortunately, such a system has a lower efficiency than the previous direct burning system. This must be so, since, to produce the same turbine inlet temperature and therefore the same output from the turbine, more fuel must be burned to balance the flow of heat passing out with the flue gases from the furnace. Whatever the thermal ratio in the air boiler, then the total thermal efficiency of the cycle will be much lower than in the direct burning cycle. So, as a generator of power, it is potentially not good enough, unless the heat in the turbine exhaust can be put to a good purpose elsewhere.

If the hot exhaust air from the turbine is used to feed the furnace, then less heat will be required to raise the furnace gases to the temperature necessary to give the desired turbine inlet temperature. This arrangement is shown in Fig. 5. Note that with this cycle all the waste heat is concentrated in one exhaust which consists of combustion products. Fresh hot air can be obtained if required, however, by bleeding off some of the turbine exhaust air before passing the remainder to the furnace.

Efficiencies

The efficiency of the cycle, outlined in Fig. 5, is 18 per cent. Therefore, it follows that apart from some very small losses in the cycle due to leakages, radiation and friction, about 74 per cent of the heat energy supplied by the fuel must be passing out from the exhaust, and it is quite feasible to recover a proportion of this heat in some type of waste heat boiler. Fig. 6 shows this elaboration of the previous cycle. The amount of recovery of heat from the exhaust in such a boiler will depend in large measure on the surface area furnished and therefore on the size and cost of the unit. Very tentatively, we can assume an efficiency of some 45 per cent in which case the total efficiency of the cycle would be of the order of 51 per cent if we total up power and process steam supplied. The total thermal efficiency is not the best that can be obtained although the result can be improved by raising the efficiency of the waste heat boiler. We can arrange for this by incorporating a back-pressure turbine in the processed steam supply line (see Fig. 7). Although this means that we shall be back to the familiar schemes for this part of the power supply, it should be remembered that, due to the production of power by the gas turbine, it would be unnecessary to pass any steam to a condenser.

Practical Application

The difficulty with the foregoing schemes, exemplified in Figs. 6 and 7, is that the thermal efficiency of the cycle is restricted by the high-temperature limitations of the air heater and turbine. It will be observed that, in one sense,

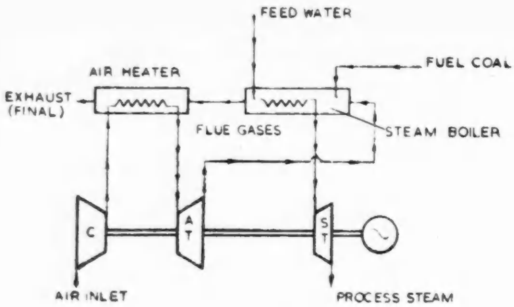


FIG. 8.

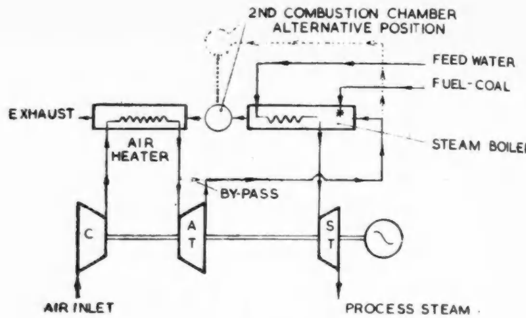


FIG. 9.

the steam boiler and the air heater are really 'playing out of position', in that the air heater is subjected to the high gas temperature whereas the steam boiler operates at much lower exhaust temperatures. By reason of the better heat transmission from steam, the tube temperatures in a steam boiler are more nearly approaching those of the steam rather than the gas, whereas in an air boiler the reverse is the case. Consequently, in the schemes considered, apart from questions of efficiency, the air heater might very easily be the stumbling-block. In any case, it is certain that expensive materials would have to be used in its construction which could well put the scheme out of court. There does appear to be a solution, however, which has certain attractive features.

If the position of the air heater and boiler are reversed in the schemes considered, we then have the situation that it is the steam boiler that gets the high-temperature gas whereas the air heater gets the gas exhaust at a much lower temperature (see Fig. 8). Thus, both units would be operating in conditions that experience has already shown us they can handle. The steam raiser ceases to be a waste heat boiler but just another steam boiler, whilst the air heater becomes the customary heat exchanger used in many gas-turbine engines. There need be nothing special about the steam boiler other than that it is likely, in certain cases, to be required to have the rather unusual properties of a low thermal ratio or efficiency in order that enough heat may be left in the exhaust gases to supply the gas turbine. The proposition in fact appears to be a perfectly feasible one, based to a very large extent on existing knowledge. An approximate estimate of the total thermal efficiency of the cycle in Fig. 8 has been carried out.

Having got this far, however, we must consider in an elementary manner the question of control. In other words, having satisfied ourselves that it is possible to make out a scheme that has prospects of a good efficiency at the design load condition, we must consider what arrangements can be made to cover the case, for example, where process steam is to be maintained and power reduced or vice versa. As the scheme stands in Fig. 8, we should have the position that as one item is reduced so is the other. The proportion of one to the other will not remain the same but, for any given percentage load in a given installation, the proportion will be fixed in advance by the design condition. To overcome this, it is suggested that we put in a second combustion chamber as shown in Fig. 9. Alternative situations are shown for this combustion chamber, the first in the direct main stream of gases from the boiler to the air heater and the second in a by-pass from the air turbine exhaust leading into the main stream again before the air heater. The particular circumstances of a specific installation would probably determine which arrangement to use but, in either case, the effect would be that, if steam requirements fell in relation to power requirements, then the fuel supply to the boiler could be reduced and the power maintained or increased by burning fuel in the second combustion chamber.

In the case where power is to be reduced whilst maintaining steam supply this could, of course, be easily achieved if the generator could be arranged to supply current to the grid. Alternatively, some waste seems inevitable and it would have to be arranged to bleed off or by-pass the air turbine, thus leading the hot air directly into the furnace supply line. The loss of efficiency would not be great since a good proportion of the heat energy in the air would be picked up again in the boiler and air heater.

The basic idea of combining steam and gas turbines seems to have interesting possibilities for waste heat users, and there are probably many variants of the schemes shown which would probably be of use in certain circumstances.

Phosphorus and Life

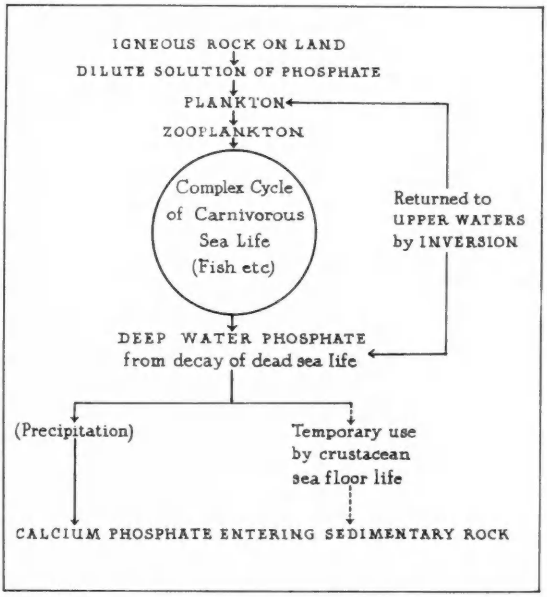
D. P. HOPKINS, B.Sc., F.R.I.C.

Of the truly mineral elements—those found in the earth's crust of rock—phosphorus undoubtedly has the greatest biological significance. In the strictest sense of objectivity all elements that are essential for the growth and maintenance of living matter are equally important whether required in large or small amounts. However, the major role of phosphorus has compelled special attention since the first days of nutritional and agricultural science, and centuries before scientific interpretation was possible the vital importance of materials containing phosphorus was widely known.

The natural occurrence of elementary phosphorus is exceedingly rare and transient for it combines spontaneously and vigorously with oxygen. Even the oxide that is formed, the pentoxide, has a very brief existence for it rapidly absorbs water and combines with it to produce phosphoric acid. It is as simple or complex phosphates, which are the salts of phosphoric acid, that most of the world's supply of phosphorus is distributed. A proportion of the earth's phosphorus is continually passing out of the mineral reserve into living matter; similarly, phosphorus is continually passing out of living matter and re-entering the mineral reserve. These circulations take place within two cycles, a land cycle and a marine cycle. Although each of these cycles can be separately described, they are in fact interconnected; indeed, losses of phosphorus from one cycle become gains for the other.

The initial source of the world's phosphorus was the sun. Spectroscopic analysis shows that the sun's atmosphere is fairly high in phosphorus content. In the formation of the earth by the condensation of solar matter, much of the phosphorus then present was enveloped in the earth's outer shell of siliceous matter. All igneous rock contains phosphorus, mainly as apatite, a complex form of calcium phosphate. The first biological organisations of matter took place in the seas and the marine cycle of phosphorus utilisation long preceded the land cycle.

If the silicate rock surface of the earth imprisoned solar phosphorus, so, too, the large water surfaces must have acquired some supplies of the element. In an aqueous solution phosphates would have maintained a simple chemical form much longer than phosphates fused in rock composed largely of other complex-forming minerals. It is possible, therefore, that the first uni-cellular living organisms of the sea were able to obtain their phosphorus requirements from this original solar supply. Even so, it would have been a limited source of phosphorus, in time becoming inadequate for the demands of expanding marine life. The principal store of phosphorus was in the land's igneous rock surface. Although apatite is insoluble in water, it is slowly and slightly dissolved by carbonic acid (formed when carbon dioxide dissolves in water). Rain water, thus acidified, steadily extracted minute amounts of phosphate from the apatite. There were then neither soils nor land plants to utilise any of this dilute solution of phosphate as it ran off into streams and sea-bound rivers. But in the seas the phosphate could be promptly utilised by marine plants.



Higher forms of sea life evolved. Then, as now, one form of life in the seas fed upon another. The same 'quota' of phosphorus could support a succession of lives and thus be indefinitely retained within the biological sequences of the marine cycle. The initial assimilation of phosphate is largely made by algae, minute diatoms which multiply by self-division like yeasts; but their synthesis of phosphate and other simple nutrients in the sea's solution is dependent upon a supply of energy from sunlight (i.e. they are photosynthetic) and their floating existence is confined to the upper levels of the sea. In the mass these algae are known as plankton. Plankton is the food for zooplankton, larger and longer-living forms of very simple sea life. Young fish when hatched feed first upon the plankton and then upon the zooplankton; later, however, most sea fish feed carnivorously, upon other species and even upon their own species.

However, all sea life does not die by becoming the diet of other organisms; were this so, there would be no losses of biologically organised phosphorus from the marine cycle. A large proportion of sea plants and sea animals die naturally. Their remains sink to lower depths. The eventual decomposition of this organic matter returns the phosphorus (and other nutrients) to the sea. But most of this liberation takes place at depths beyond the sun's penetration; the simple nutrient-assimilating organisms are not present to re-mobilise this phosphate. There is, therefore, in the lower water levels of the seas a steady building up of phosphates and other nutrients. However, this phosphate is not accumulatively retained in the sea

solution. Some of it is assimilated by crustacean and other bottom-living organisms; much of it is steadily precipitated to the sea-floor; and in temperate regions there are regular inversions of the upper and lower layers of sea water which result in the further utilisation of deep-sea phosphate for plankton growth.

The second of these three influences, precipitation, is largely caused by the release of calcium in the decomposition of marine organic residues. When calcium and phosphate ions meet, insoluble calcium phosphate is formed. This steadily precipitated phosphate enters the composition of *sedimentary rock*; again it eventually becomes a more complex mineral phosphate of the apatite class. Here there is an important connexion between the marine and land cycles of phosphorus. Substantial areas of what is now the land surface of the world were once covered by seas; indeed, their rock and sub-soils have a much longer past history as sea-beds. There are, therefore, two kinds of complex mineral phosphate on land—the phosphates of igneous rock originating directly from solar phosphorus and the phosphates of sedimentary rock which have formerly passed through the marine cycle.

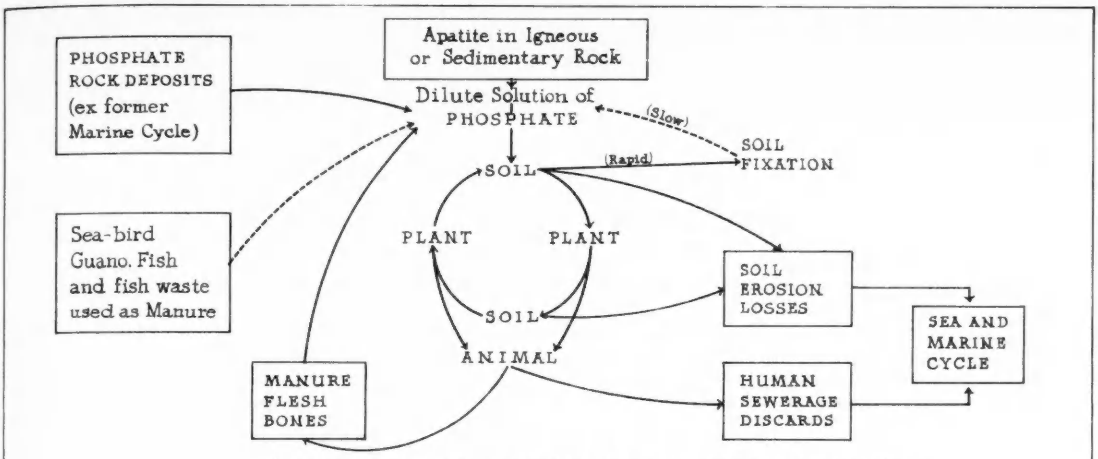
The third influence by which phosphate accumulations are removed from deep-sea waters, by the inversion of upper and lower sea layers, is not yet fully understood. In all seas the surface waters are warmed by the sun and they therefore become lighter so that, without some intervening disturbance, the colder and heavier water below cannot rise. In marine science the boundary between the upper part, which extends some forty yards down, and the cold lower part is known as the thermocline. In temperate regions the autumn cooling of upper waters leads to a breakdown of the thermocline and there is a seasonal rising of the lower and nutrient-rich waters; but in tropical regions the surface waters remain permanently warmer and lighter and there is no seasonal breakdown. This is the explanation of the comparative absence of good fishing-grounds in the tropical parts of the world. But there are other factors that promote inversion in particular sea areas; a contoured shape of sea-bed coupled with the seasonal breakdown of the thermocline may create rising bottom currents which produce a more thorough and persistent mixing of the lower and surface waters. More than one complex theory of this hydro-dynamic nature has been put forward to explain the exceptional amount of inversion that occurs at the Dogger Bank in the North Sea. But whatever the detailed explanations may be, all the deep-sea fishing grounds are places where an exceptional uprising of bottom water takes place. With it, of course, a supply of nutrients, particularly phosphate, is brought into the sunlit zone of plankton growth.

It is clear that only a limited recovery of deep-sea phosphate can be expected. The inversion or sea-mixing influences are occasional rather than perpetual; and they are strongly exerted locally rather than generally. But the removal of phosphate from the sea by precipitation can take place steadily. In its simplest form the marine cycle for phosphorus may be summarised as follows: but for the steady flow of fresh phosphate from igneous rock, the losses by deep-sea phosphate precipitation would have prevented any lasting expansion of sea life. Even with this constant land source of phosphate additions, it is clear from modern fishery research that a shortage of phosphate in the surface waters is the principal limitation to sea life.

The land cycle of phosphorus began much later. First came the invasion of dry land by plant life. Initially the medium of growth was the layer of fine mineral particles derived from rock weathering, the simple plant nutrients being provided by the rock-extracting power of carbonic acid. Later, with the decay of dead plants, organic matter and humus that entered the medium and top-soils of the kind we know today began to develop. As plant life increased its land invasion a larger amount of the phosphate dissolved from apatite was taken by plants. It is possible, however, that plant growth and soil formation accelerated the rate of apatite extraction; for the accumulation of organic matter on the land surface with its concomitant production of carbon dioxide by decomposition is likely to have increased the amount of carbonic acid attacking surface rock and rock-derived subsoil.

In any case, some of the phosphorus needed for further plant growth was provided by the decomposition of previous plant material. The invasion of animal life enlarged and complicated the economy of the ROCK→PLANT→SOIL→PLANT cycle. Only a portion of the phosphorus taken by animals from plants was speedily returned to the soil. The reason for this is found in the twofold function of phosphorus in animal life. It is not only an essential constituent of all cell nuclei but also a major constituent (as calcium phosphate) of bone substance; it has, therefore, a dynamic 'life process' function and a less dynamic structural function. Nearly 25 per cent of the total mineral content of an animal body may be phosphorus but as much as four-fifths of this amount is held as calcium phosphate in the skeleton. In the final decomposition of the animal body after death, the phosphorus in the flesh will be fairly quickly returned to the soil; but the decomposition of solid bones is exceedingly slow. So, in the SOIL→PLANT→ANIMAL→SOIL sequence, the final closing of the cycle involves, at any rate for as much as 80 per cent of the animal-assimilated phosphorus, a serious time-lag.

Did the expansion of plant and animal life on land with its increasing utilisation of rock-derived and dissolved phosphate reduce the flow of land phosphate into the sea and the marine cycle? There would seem to have been always a sufficient release of soluble phosphate from the land to the sea, a fact that supports the idea that soil formation and plant-life led to an increase in the previous rate of rock denudation. There is, however, little 'washing out' of phosphate from soils by rain for the actual existence of soluble phosphate in soils is quite brief. Like other nutrients, phosphorus can be assimilated by plants only when it is available in the soil solution. But if phosphate in the soil solution is not quickly removed by plant uptake, it is precipitated by other soil constituents. Insoluble calcium phosphate is readily formed; however, this need not be a long or permanent withdrawal from the 'system' for calcium phosphate can be equally readily redissolved by weak soil acids. But iron and aluminium phosphates are also formed (especially in acid soils) and from these compounds phosphate recovery is slight and slow. These processes are known as *soil fixation*. Soil fixation prevents a considerable proportion of the 'biological currency' of



SIMPLE DIAGRAM FOR LAND CYCLE OF PHOSPHORUS CIRCULATION

phosphorus in the SOIL→PLANT→ANIMAL→SOIL sequence from re-entering the cycle when it returns to the soil. Instead, it enters the soil's reserve of unavailable or not easily available phosphate. There is some resemblance in this to the steady loss of deep-sea phosphate from the marine system. (It is possible that a tiny fraction of the fixed soil phosphate enters the marine cycle; for some of this accumulation in top-soils will pass downwards by gradual and physical movement. In contacts with ground waters the fixed phosphates will be at least as extractable as the apatite of igneous rock. These ground waters, out of reach of most plant roots, making their way to streams and rivers, will carry some of the phosphate to the sea.)

The slow and almost timeless balance of the land cycle was greatly disturbed by farming. Agriculture meant the ever-increasing growth of cereal plants for feeding man and his domestic animals upon the seeds or grain, those parts of the plant in which most of the soil-derived phosphorus is concentrated. As proportions of total mineral needs, man and animals require more phosphorus than plants (about 24 per cent compared with 16–17 per cent). The fact that seeds are concentration centres for the phosphorus in plants is a major reason for the development of cereal grains (wheat and rice) as primary foods for the animal kingdom. But as a result far more phosphorus was removed from soils than was returned. Early farming was nomadic, a steady movement from soils whose fertility had been extracted to virgin soils maintained in a state of mineral sufficiency by the cycles which circulate nitrogen, phosphorus and other elements. Three devices were in time discovered: (1) returning animal manures to soils; (2) fallowing, i.e. periodic and temporary returns to the natural cycles; (3) crop rotation. But none of these could indefinitely return a sufficient amount of phosphorus to soils as human populations increased and sharpened the demands for cereal foods. They could be incomplete remedies only because so much of the phosphorus acquired by man and animals passed into bone substance whose phosphate return to the soil was so slow.

In the seventeenth and eighteenth centuries the usefulness of bones as a fertiliser was gradually realised, particularly when it was found that their effectiveness was increased if they were first ground finely. But it was not until 1795 that the first suggestion was made that the principal virtue of bone material lay in its phosphorus content; nor did this become really understood until Liebig in 1840 published his theory of mineral plant nutrition. Nevertheless, bones were extensively used as a fertiliser before 1840, particularly in England. Thus in 1815 we find Liebig attacking England for her bone-importing activities: "England is robbing all other countries of their fertility. Already in her eagerness for bones, she has turned up the battlefields of Leipzig, Waterloo and the Crimea; already from the Catacombs of Sicily she has carried away the skeletons of many successive generations. . . ."

It was Liebig himself who indirectly solved the problem of bone supply. He suggested that treatment of bones with strong acid would give a more soluble phosphatic fertiliser. In England Lawes put this idea into practice, thus founding the superphosphate industry. Finding the supply of bones inadequate to meet the demand for superphosphate, Lawes experimented with phosphorus-containing minerals and found that an equally effective superphosphate could be based upon these mineral sources.

The existence of richly phosphatic mineral deposits in various parts of the world is not a fortuitous legacy from the earth's original formation by solar condensation. These deposits exist as a result of the marine-cycle movements of phosphorus. It is not fully understood why these exceptional concentrations of mineral phosphates occur at certain places on the exposed sedimentary rock surface. Several explanations have been put forward and it is possible that no single explanation accounts for all the deposits. Sudden temperature changes in the sea once covering these sites may have caused enormous mass destruction of life among sea animals and organisms; heavy destruction of sea life through causes of this nature are not unknown today. Abnormally high precipitation of

phosphate together with the deposition of bone phosphate would follow. Bottom water currents in the sea may have set up chemical disturbances resulting in an intensified precipitation of deep-sea phosphate ions. Another explanation is that sea-floor currents and the local contour of the sea-floor itself have segregated the precipitated calcium phosphate and prevented it from entering siliceous dilution in sedimentary rock itself. Whatever their true explanations may be, the fact remains that marine-cycle losses of phosphate have in various places accumulated in concentrated 'rock phosphate' forms instead of penetrating siliceous rock as a minor diluent.

The first mineral phosphates used by Lawes were from nodulated deposits (coprolites) in Suffolk and Cambridgeshire. Until 1900 various nodule deposits in England were worked, but in the period 1850–1900 many much richer phosphate rock deposits were found abroad, notably the huge beds of North Africa, America and Russia. A large and widespread industry has arisen to produce superphosphate and other phosphatic fertilisers from these minerals deposited as a result of the marine cycle. By this means the agricultural acceleration of the land cycle is at least partially compensated, though as human numbers increase and demands for cereal crops intensify, more and more phosphatic fertiliser is required.

It is pertinent to consider how long this intervention of man can preserve a balance. The known world reserves of suitable rock phosphate are put at 26,000 million tons. A high estimate of world use of all phosphatic fertilisers is 25 million tons a year. But, with world population increasing rapidly and with the use of fertilisers still only partly established in some of the large crop-producing regions, a high estimate must be taken in making any long-term prediction. There would seem to be enough rock phosphate in known and workable deposits to last for another thousand years.

The phosphorus in fertilisers is just as exposed to the processes of soil fixation as is the soil's own supply of available phosphorus. Even in favourable conditions not more than 25 per cent of the added fertiliser phosphorus enters current or subsequent crops. Despite considerable study by twentieth-century science, this problem remains unsolved. The discovery of a phosphatic fertiliser producible from mineral phosphate, which would (*a*) remain highly available to plants and (*b*) resist soil-fixing influences, would greatly reduce the world's annual consumption of mineral phosphate reserves. At present, however, the best that can be done is to prevent a minor proportion of the fixation loss by soil-management practices, e.g. liming to reduce soil acidity, placing fertilisers in bands instead of broadcasting them and thus reducing soil contact. There is some evidence that soils with a high content of organic matter fix phosphate less severely.

The continuous outflow of sewage from most centres of population represents an enormous loss of phosphorus from the modern land cycle. The human animal, except in countries such as China and Japan, no longer conserves his own organic wastes. With the widespread introduction of water-closets, these wastes are voluminously diluted and eventually pass down rivers to the sea. Only a small fraction of the phosphorus so involved is recovered. Liebig in his denunciation of England's heavy use of bones stressed this point. "England annually removes . . . from other countries the manurial equivalent of 3½ million men, whom she takes from us the means of supporting, and squanders down her sewers into the sea." It has been estimated that the phosphorus in the sewage from 5,000,000 people is equivalent to 17,000 tons of rock phosphate per year; Britain's current annual wastage must be at least the equivalent of 160,000 tons of rock phosphate (while she imports some 1,200,000 tons of mineral phosphatic fertiliser materials).

A more serious loss of phosphorus in the modern world is probably that caused through soil erosion. When millions of acres of top-soils are blown or washed away, several hundred pounds of phosphorus (available plus fixed) are lost with each acre. The annual loss of phosphorus by erosion in the United States was estimated in 1930 to be more than 2,000,000 tons. And we are still only on the verge of reversing the widespread erosion of soils even in those countries where the problem has been seriously and determinedly faced.

Both the loss by soil erosion and the loss by sewage outflow—man-created losses—are conserved by the marine cycle; whether conducted through sewers, washed away into rivers, or blown away in dust storms, most of the phosphorus thus removed eventually reaches the sea, where a great part of it will be assimilated by plankton.

A very minor but interesting link between the land and marine cycles has not yet been mentioned. Certain oceanic islands, rocky and uninhabited by man, and in almost rainless areas, are regularly used by sea-birds (pelicans, albatrosses, etc.) during their breeding season. Their excreta and the bodies of young birds that die accumulate. Rain would wash out the phosphate but instead the sun dries and concentrates this material. As these birds feed entirely upon fish, their organic wastage is directly derived from the marine cycle's 'phosphorus currency'. This naturally dried material has long been known as guano. Guano islands were exploited as a source of manure by the Incas. In more recent times the most famous guano islands, off the Peruvian coast, have yielded 10,000 tons of guano a year. Guano collection is illegal during the four-months' close season when the birds flock to the islands; similar protective regulations are said to have been imposed by the Incas. Today the total contribution of guano is insignificant compared with the millions of tons of mineral phosphate brought into the land cycle. Nevertheless, it represents a unique transference of phosphate and other nutrients from the sea to the land.

Is modern man to be indicted for his agricultural acceleration of the land cycle? An adult requires just over one pound of phosphorus per year as a maintenance standard. Many of the world's soils are exceedingly deficient in available phosphorus. Since 1800 the world's human population has more than doubled. The marine cycle's deposits of concentrated mineral phosphate took many millions of years to accumulate and they are being consumed at an exhaustion rate to be measured in centuries. Yet it is difficult to see how man, faced with so vast an increase in his numbers, could have done otherwise. If there is any indictment, it rests upon the charges of wastage, upon the huge losses in sewage and the even greater losses through unchecked soil erosion.

Clifford Troke*

by LESLIE PAUL

To you, listeners all over Europe, Clifford Troke was a voice—a generous, human voice from which, I'm sure, you caught the warmth and kindliness of the man: but to me, well, he was my oldest friend and to speak of him now is not an easy task. But you would like to know what kind of a man it was behind that voice, and perhaps I can make that plain.

Clifford came from the West Country and he had a pleasant Dorset burr in his voice, and he was trained as a doctor. He was still at medical school when I first knew him. Then something went wrong financially—he could not finish his training, and a doctor of genius was lost to the world. But even then half his interests were in literature. He was writing and publishing stories and poems, and his knowledge of his favourite authors was so great that he could outquote anyone that I knew. His literary powers and his medical training determined his life. There was one thing more, the dream of our youth, a youth which was spent at the end of the First World War, the dream of a world made clean and shining by science, of poverty and disease brought to an end by science. His was to be a life more devoted to the task of explaining the increasingly complicated corpus of contemporary science to the man in the street. But there were many side thrusts into all sorts of occupations before he arrived at the best work of his life—a trip in which he worked his way to the United States and across them, a successful news-service run in Fleet Street, and days and nights as an A.R.P. chief in one of the worst battered London boroughs during the blitz. He had political interests, too. Nearly all his life he was a member of the Labour Party, one of those loyal and devoted ones, without personal ambition, who are the mainstay of a political party. His political faith was part of his belief in the necessity for a new scientific approach to social problems. Of later years he fell away from this early faith. He felt that mixed with the rational, reforming socialism of which he approved were spites and hatreds which ruined its power to speak for all fair-minded people. He left the party sorrowfully, and expressed himself in a brilliant aphorism which deserves to be remembered and which reveals his power over words. He said—"When I was young I thought socialism was the mathematics of justice, now I discover it to be the arithmetic of envy."

When he came to his post as scientific correspondent in the European Service of the BBC five years ago, he was rich with experience, an able journalist, and singularly gifted in seizing and revealing the dramatic, the exciting, the momentous news concealed at the core of the prosaic communiques from the scientific front. And to put himself right in the picture he travelled anywhere in all sorts of conditions—out to sea to watch cable-laying, or to Harwell or Whitehaven to inspect atom plants. He had a genius for catching at the phrase which would make the ordinary man sit up when he talked about these things. Sometimes it went against him as when he wrote about "A Crane that Walks". "Come, come," friends said, "we know your gift for analogy—but, after all, 'A Crane that Walks'—don't expect us to believe that." But I happened to see that crane too, and it really did walk, a monstrous 100-ton thing which lifted great clodhopping feet and lurched along like a man from Mars out of an H. G. Wells novel. Clifford Troke, indeed, saw how fantastic much of modern science had become, and he rejoiced in it and exploited it, and noised it abroad, because he was fundamentally a poet.

He didn't think of himself as such. He believed himself to be strictly a rationalist and scientist. We once had a talk together on philosophical matters on the radio in which he spoke of himself as having gone on steadily all his life with his scientific thought, thinking always in terms of hypotheses which must be tested and proved; this was his field and he regretted he would not follow others into their mysticism. There was a hint of reproach that I had abandoned the scientific path we had both shared when young. He wasn't quite right about himself. Of course I acknowledge the genuineness of his passion for science, but he brought to science something much more than the feeling of the method of a plodding research worker. In conversation it was plain how much he lived by great and sometimes astounding leaps of intuition, and how much we, his friends, looked to him for those leaps, and thrived on them ourselves. He was indeed in love with the poetry of science. He felt no need for a religious or mystical approach to life because the scientific world was in itself a brilliant enough kingdom. When he talked of the role of microbes in the human economy, or of the manner in which viruses seemed to spring spontaneously into existence in the blood stream, one caught the awe and surmise in his mind. In the face of the treasures and accomplishments of science all reservations (such as I might make) seemed to him paltry and lacking in generosity; in face of the brilliant revelations of nature and immensity of the universe, all other Revelations seemed thin.

* Clifford Troke, scientific correspondent in the European Service of the BBC, will be remembered by readers of DISCOVERY for his several contributions. The above appreciation was recorded by his friend Leslie Paul and broadcast in the BBC Overseas programme.

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3. Cell division in a root , unstained.

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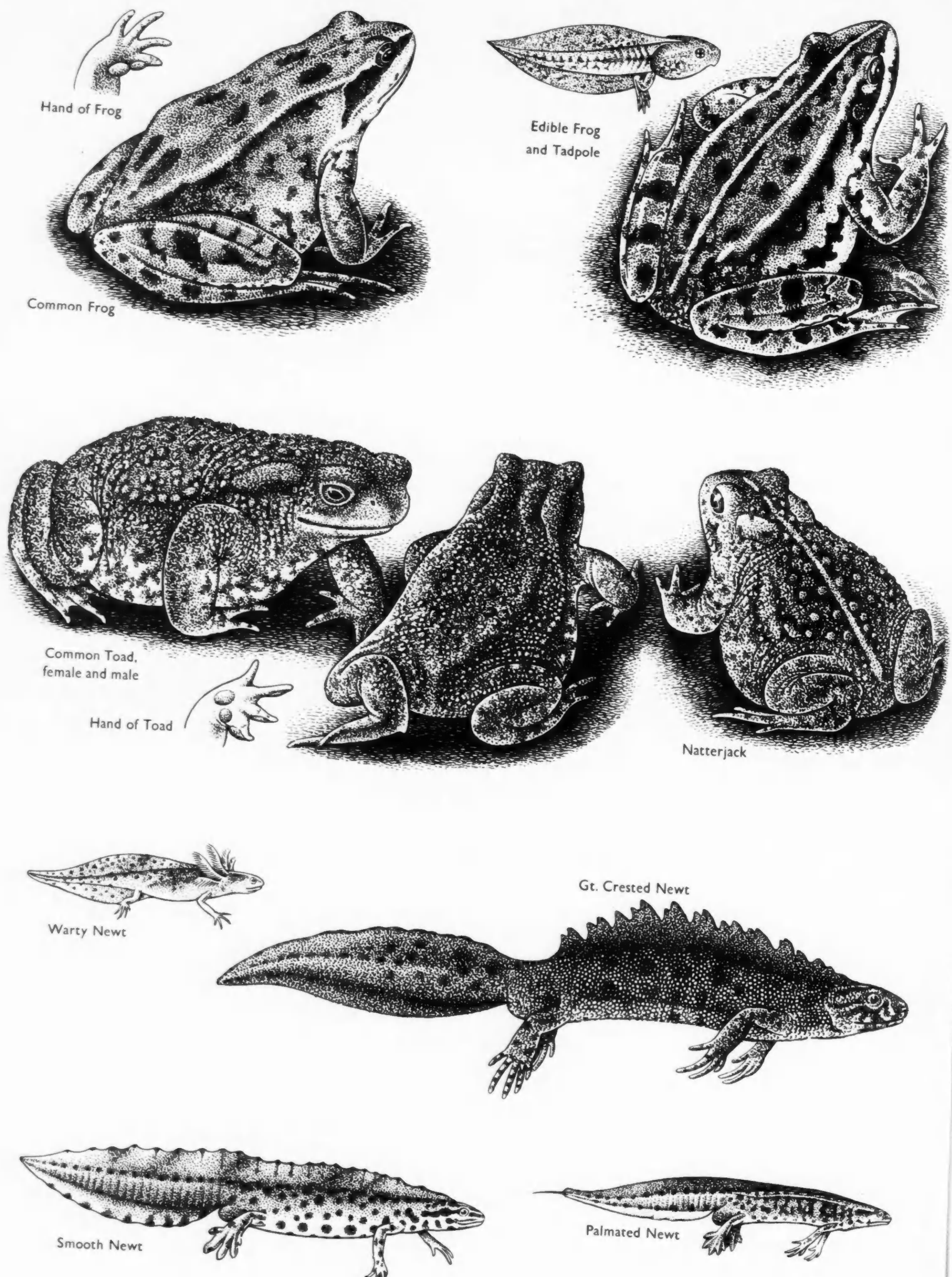

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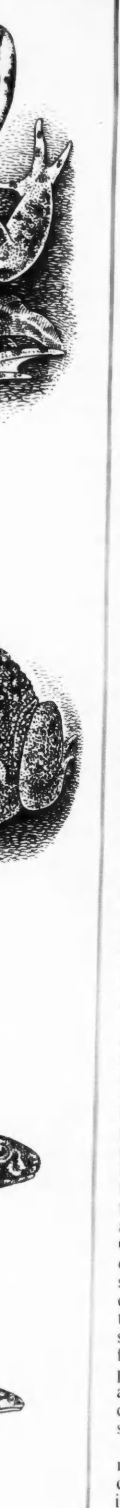

The Habits of British Amphibia

ALFRED LEUTSCHER, B.Sc.

It is true to say that we do not know an animal until we have found out everything about it—living or dead. It is a paradox in biology that more is usually known about the dead animal in the laboratory than its living counterpart in the field. This situation can only be remedied by the field naturalist who meets his subject on its home ground.

It is general knowledge that British amphibians gather in ponds in springtime to breed, yet there are many unsolved problems concerning even this common, yearly occurrence. For example, what is the factor which stimulates a frog to lay her eggs at a certain period? The earliest breeding days occur in the Common Frog (*Rana temporaria*). In the west country spawn may be found as early as February. For most of England spawning takes place during March, and in Scotland may be delayed until April. Temperature would seem to be the controlling factor, since frogs are cold-blooded and forced into inactivity during the winter period, called hibernation. This is theoretically prolonged later into the new year, the farther one travels northwards. One might also expect frogs at higher altitudes to spawn later than those at sea level. It has actually been found that, up to certain altitudes, the higher the pond, the *earlier* is the date of spawning.

Sunshine may play a part in this. It is now known that the jelly-like covering of the eggs makes an excellent incubator, and retains the heat from the sun's rays which are absorbed by the pigmented eggs within, so that their temperature is actually higher than that of the surroundings. This may explain why early spawn which is frozen in ice is not killed, and will develop after the thaw.

Temperature and sunshine are not the complete answer. Frogs have been observed to assemble at a spawning site, pair off, then hang about quietly for a whole week as if waiting for some signal before laying. An ingenious theory has been suggested to explain this so-called pre-spawning period, namely, that the spawning factor is the availability of food for the future tadpole. The main diet of a young tadpole is the plant called a filamentous alga, upon which it browses voraciously. Growth of these algae is determined not only by temperature and light, but by the supply of mineral salts. A rain shower could supply these, and a sudden concentration of phosphates in a pond might start off the algae. Is it possible that a female frog can detect the change in the pond odours, even the presence of algae, and decide to lay? If so, a careful watch on the appearance of algae might reveal some interesting data.

The stimulus to spawn in frogs is hormonal, but it is not yet known what determines the release of the hormone. Is it temperature, sunshine, rain, algae, or what? Only a field naturalist can find the answer.

The idea that this pre-spawning period may be due to another cause, such as the condition of ripeness of the eggs, is suggested by the Edible Frog (*Rana esculenta*), which appears in the water in early April but rarely lays before some weeks have passed. The laying period for South England is May or June, when algae are already abundant. Edible frogs are particular where they live and breed. Since their introduction to Britain over a hundred years ago they have flourished, then disappeared from many localities. Their old haunts in the Lincolnshire fens are now deserted. They like best areas dotted with many small ponds close together, and have flourished for many years in the gravel pits near Teddington close to London. There are signs that they are spreading to other ponds, including those in Richmond Park. Further records of this spread, if it continues, would be of interest.

The Common Toad (*Bufo bufo*) can be most particular in its choice of breeding site. The story of its annual migration has often been told, but the sense which directs the journey is still not known. After hibernation (late March or early April for England), the migration to the pond begins. Single males arrive first, then the main colony, and some may have paired on the way. Where the route crosses a highway there are many casualties. At one place I know of, the toads leave a woodland to cross a road to a pond the other side. For some years, every March, the same stretch of road becomes covered with their flattened bodies. At another place I found numerous toads hopping along a fence, which had been erected the previous winter, seeking out gaps through which to pass on their way to a pond just beyond. These two instances suggest a constancy and purposefulness about such a migration, in which toads will climb walls and by-pass other ponds on the route.

If one removes toads from their pond and sets them down some distance away, they are able to find their way back even from a mile distant. The call of the male, the downward slope to the pond and the attraction of water sensed in the atmosphere, have all been considered possible influences on the toad's orientation. Yet, when these factors are absent, the animal still goes in the right direction.

At the pond there is much rivalry, for the males outnumber the females. As many as six have been found gripping in a tight ball around one female. Later in the year, when the colony has dispersed and we meet an occasional toad in the garden or woodland, it is generally a female. What has happened to the smaller males? The answer is best sought by 'marking' as many toads as possible at the breeding pond. Coloured waterproof tags tied around the body can be used, or one or other of the toes amputated. As an injury this does not unduly distress a toad, and will serve in future recognition after release.

The breeding season is a good time for discovering the enemies of frogs and toads. Casualties are then highest. Predators of frogs are numerous, but appear to be limited in the case of toads. This is because of the poisonous nature of the warty skin, which secretes a venom highly irritant to the mucous membranes. A dog which picks up a toad may froth at the mouth and even go into convulsions. The heron, stoat, rat, otter, hedgehog and crow have been observed to attack toads. Where the meal is eaten the skin has always been removed, or avoided. Apart from snakes, which can swallow a whole toad, no other animal is known to eat the skin.

Common toads lead a solitary life apart from the breeding season, but the smaller Natterjack (*Bufo calamita*) is a gregarious creature, keeping together throughout the year. In Britain the spawning period extends from March to June. Unlike common toads, the natterjacks are not particular where they spawn, and may choose even a puddle which later dries up, so that the eggs perish. Near the coast brackish water is often used. How the tadpoles can exist in such waters is not known, and the degree of salinity has still to be investigated.

With the three British newts the general habits are similar. The 'homing' sense is poorly developed and there is no mass migration. All the species may be in the water by March, and have left by September. Egg laying is extended well into the summer, and young, metamorphosed newts are continually leaving the pond from June to September. Eggs laid late in the season cannot mature the same year, so that 'overwintering' of the tadpoles is common.

There are some ponds in which newt colonies remain in water throughout the year, yet in ponds near by they may all be out by late summer. What is the peculiarity of these occasional ponds which encourage an aquatic life? Other sites produce curious individuals which, as it were, fail to grow up. They reach adult size, but retain the larval state. Their colour is usually a creamy white and the gills are pink. Such a condition, a constant feature in the Mexican Axolotl, is known in the British Smooth and Palmate Newts, but not in the larger Warty Newt. It is called *neoteny*, and often turns up more than once in the same place. What encourages neoteny in these waters? The external cause is still unknown, and the environment bears investigation. Internally it is known that there is something abnormal about the thyroid mechanism. That this

may be due to an inherent factor cannot be overlooked.

The above account will make it clear that there is still plenty of field work to be done on the Amphibia in Britain. The British Herpetological Society is now actively pursuing these problems, and has circulated its members with a questionnaire. This asks for data on British frogs and toads in their local breeding haunts. Readers of DISCOVERY who are interested in such matters are invited to apply for the questionnaire at the Society's headquarters, c/o British Museum (Natural History), South Kensington, London, S.W.7.

SOME FIELD CHARACTERS:

Frogs: Skin usually smooth and moist. Body slender, limbs long. Movements active. A good swimmer. Male has thumb pads.

Toads: Skin usually dry and rough. Body squat, limbs short. Less active and a moderate swimmer. Male has finger pads.

Newts: Skin dry on land, but naked. If scales are present animal is a lizard. Males have a crest in breeding season.

Common Frog: Look for patch behind eye. Found all over Britain, including Ireland. Soft croak. Size 3 inches.

Edible Frog: More slender, nose more pointed, pale stripe down back. Much more active and very aquatic. Main breeding colonies are in Richmond area, Surrey; at Otford, Kent; and Hampstead, N. London. Song very loud. Size 3 inches.

Common Toad: Large size, especially female. Large glands on neck. All over Britain, except Ireland. High pitched croak. Female 4 inches, male 2½ inches.

Natterjack: Smaller, legs shorter, runs instead of hopping. Pale stripe down back. Gregarious. Main areas along sandy coast of Kent, Lincolnshire, Lancashire and S.-W. Scotland, also C. Kerry in Ireland. Inland in Surrey and Hampshire. Song loud. Size 2½ inches.

Smooth Newt (*Triturus vulgaris*): Very common over most of Britain, including Ireland. Male has a wavy crest. Size 4 inches.

Palmate Newt (*Triturus helveticus*): Local, absent from Ireland. Male has straight crest, black webs between toes and thin filament at end of tail. Size 3 inches.

Warty or Gt. Crested Newt (*Triturus cristatus*): Local, absent from Ireland. Male has high, serrated crest. Size 6 inches.

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*Good field book for the pocket.

POLLUTION FROM RIVER DERWENT—*continued from p. 92.*

years, bceause it would be impossible to shut down the whole of the Derby sewage system and flood the town. The corporation were not offering to submit to an injunction of any sort.

Mr. Salt, for the British Electricity Authority, said that their attitude was that their actions mitigated rather than increased the pollution of the river. The authority were prepared to investigate to see if they could do anything to help the plaintiffs, but it would take time and it would be expensive. The authority said they did nothing lethal *per se*, and that they helped the breeding of the fish. They admitted that the river was polluted below Borrowash Bridge.

Mr. Russell said that that attitude of benevolence on the part of the Electricity Authority was a novel one to the plaintiffs.

Expert Evidence

Evidence was then called for the plaintiffs.

Dr. Eric Forrest, lecturer in zoology at London Unisity, said that the condition of the river above the defendants' premises was reasonably clear. Below the corporation's sewage outfalls it was dark and turbid, and fouled by untreated sewage. Below the British Electricity Authority's works the water was steaming and loaded with matter, including sewage fungus. There was a smell of putrefaction and acetic acid. The bed of the river was black mud, putrefying and disgusting. The pollution went in stages. At the first stage the more sensitive fish such as trout and grayling disappeared. Coarse fish like pike and tench might survive the second stage. In the third stage the river contained sewage fungus. In the fourth stage the river was completely dead.

The temperature of the water in the river varied considerably owing to the discharge of heated effluents into it, and this was harmful to fish. Having inspected the Derwent from Borrowash Bridge down to Derwent Mouth, he formed the opinion that it was unfit for fish life.

Cross-examined by Mr. Henry Salt, Q.C., for the British Electricity Authority, Dr. Forrest said it would take two or three years to purify the Derwent by natural means. He did not agree that breeding of fish might be encouraged by heating the water. (The above report has been adapted from the reports published in *The Times*, by permission.)

Water Pollution Research

A. GRAHAM THOMSON

When Æsop wrote his fable about the wolf and the lamb drinking together at the same stream, he could not foresee that, 2,500 years later, the survival of civilisation itself would depend on the ability of scientists to preserve the world's water resources from pollution.

The Industrial Revolution of the nineteenth century created a new and critical problem for mankind. Large manufacturing centres sprang up on the banks of rivers or streams, into which enormous quantities of domestic sewage and waste waters from industrial processes were discharged. In some areas conditions soon became so bad that factories requiring clean water for manufacturing processes were compelled to move to other districts where the river water was not polluted. Sparkling streams abounding in trout or salmon were transformed into vast sewers whose waters were toxic to fish.

The problem of pollution is particularly difficult in Britain, where the rivers are small and industrial populations are crowded into limited areas. It has been estimated that about three-quarters of the country's population receives its drinking water from sources which have to be protected against undue pollution. Without effective control measures, we should soon be exterminated by the poison from our own waste products.

The dangers of pollution have been appreciated for nearly a hundred years. In 1865 and 1868 commissions were appointed to investigate the disposal of domestic and industrial waste. Other enquiries followed, by far the most important investigation being undertaken by the Royal Commission of 1898. This commission took evidence from municipal and river authorities, sanitary engineers and manufacturers. Experimental work was also undertaken both in the laboratory and on a large scale.

By 1915, when the last volume of the Royal Commission's report was published, considerable progress had been made in the treatment of polluted liquids. Fifty years ago domestic sewage was already being treated on a large scale by irrigation on porous under-drained land, often after the sludge had been removed in sedimentation tanks. By this treatment it was possible to obtain an effluent which could be discharged to a river without causing undue pollution.

Investigators discovered that the changes which occurred as the liquid percolated downward through the soil were due, at least partly, to biological activity. Efforts were made to increase the efficiency of the treatment so as to reduce the area of land necessary and make it possible to use the process on land which was unsuitable for irrigation. This work led eventually to the development of biological filtration, in which the large area of top soil, containing particles of various sizes, is replaced by a filter bed of well-graded stone or other durable material, specially built ventilators being provided at the bottom to aerate the bed. Advances were made in the treatment and disposal of the sludge removed from the sewage by sedimentation. Some success was also achieved in the treatment of industrial effluents.

Despite this progress many streams in industrial areas were very badly polluted and fresh problems continued to be presented, both by the development of new manufacturing processes* and by the growing volume of good-quality water required for domestic and industrial use. One of the recommendations of the Royal Commission was that a permanent authority should be established to continue its work. This step was taken in 1927, when the Water Pollution Research Laboratory was set up by the Department of Scientific and Industrial Research.

At first this organisation was very small. It had an office in London and temporary laboratories were established in various centres to investigate specific problems. During the war the question of pollution became increasingly important. New industries were established, existing firms outgrew their factories, and plants were set up for strategic reasons in country districts, where only a limited water supply was available for diluting the waste liquors. It was, therefore, decided that a permanent station was required. This is to be built at Stevenage and should be ready for occupation in 1953. Meanwhile the organisation has been given temporary accommodation at Watford, Herts., and additional laboratories have been provided at the Building Research Station at Garston, a few miles away. Since the investigation of pollution problems frequently necessitates the establishment of pilot plants, there are also a number of out-stations where experimental work of a short- or long-term nature is in progress.

During the past decade the staff of chemists, physicists and biologists has grown from eight to almost sixty; yet so numerous are the inquiries received that priority has frequently to be given to urgent problems at the expense of fundamental research. Investigations into specific problems are undertaken in close collaboration with consulting engineers, and as soon as the work is sufficiently advanced the design and construction of plant are left to the authority or industry concerned. To cover its vast field the Water Pollution Research Laboratory incurs an annual expenditure of £53,000. This figure is misleading, however, since in many instances the cost of the work is shared by local authorities or industries.

At Birmingham, for example, 1½ million gallons of sewage per day are being treated experimentally in a plant constructed and operated by the local authority, which also built a laboratory at the site. These facilities have assisted the Water Pollution Research Laboratory to develop the alternating double-filtration process of sewage treatment, tried out on a tentative scale before the war, which has considerably increased the rate at which sewage can be handled. Birmingham are now converting their entire plant to the requirements of this new process, and other local authorities will also benefit from this research.

Luton discharges its sewage into the river Lee, from

* Particularly involved and intricate are the problems of disposing of radioactive sewage from such establishments as Harwell. Readers are referred to the feature on "Radioactive Sewage" in Discovery, June 1950.

which part of London's water supply is derived, and her local authority is at present under an injunction to reduce pollution. Time was limited and no solution to the problem was in sight. A pilot plant was therefore established at Luton to try out processes for the rapid mechanical filtration of sewage effluent, which had never previously been used in Britain. As a result of this investigation a plant to treat the whole of the sewage effluent by these methods is now being built.

Much of the research at present in progress is directed towards cheapening the processes in use. In recent years much progress has been made in the design and operation of percolating filters in which sewage is purified by the action of micro-organisms. Most of the latest methods are designed to allow a greater volume of sewage to be handled daily in an installation of given size without either lowering the quality of the effluent or blocking up the filter by an excessive growth of micro-organisms. In the process known as alternating double-filtration, this is achieved by alternating settled sewage with partially purified effluent from another filter, the alternations being so arranged as to maintain the total quantity of living material in the filter at a desired level.

An important part in controlling these micro-organisms is played by the small flies which emerge from filters at sewage disposal works, often in such numbers as to constitute a nuisance. The larvae of these flies, together with worms and other invertebrates, feed on bacteria and fungi and so help to prevent filters from becoming choked. The problem was to reduce the number of these flies without either exterminating them or damaging other useful organisms. This difficulty has recently been solved by the application, under strictly controlled conditions, of such insecticides as D.D.T. and Gammexane, which have a selective toxic action on fly larvae.

Though efficient methods of treating sewage have been devised, not much is known about the detailed composition of sewage and sewage effluents or the mechanism of the purification processes. Part of the Laboratory's work has therefore been directed towards obtaining basic information of this nature. Investigators have studied the amount and nature of the colloidal particles present in sewage and the effects on them of varying conditions of acidity and alkalinity or treatment with various gases. At present attention is concentrated on the amino acids, which are being separated by a method of paper chromatography.

There are various methods of disposing of the sludge from sedimentation tanks. At large works it is usually digested under anaerobic conditions and then dried on drying beds; at small works it is dried without preliminary digestion. Alternatively it may be dried by mechanical means such as vacuum filtration or filter pressing, usually after the addition of chemicals, or it may be heated under pressure and then dried in filter presses, or dried and incinerated by heat. Most of it is finally dried on open beds until it is in suitable condition to be lifted, and a large part of it is then used by farmers as manure. At some towns on the coast, including London, sludge from the digestion tanks is pumped to barges and dumped into the sea.

A very wide field for investigation is presented by the treatment of industrial wastes. Sufficient knowledge is now available to enable a method to be suggested for the treatment of many waste waters without previous experiment, but there are still many types of liquors which present new or special problems. Frequently it is necessary to study the processes which give rise to the waste waters and to determine the volume and composition of the liquids discharged. It is rarely possible to remove all the polluting substances from a waste liquor, but means must be found of eliminating or reducing the most objectionable constituents of the liquid. Treatment will depend on whether the liquor is to be discharged into a river or into a sewage disposal plant. It is also evident that a higher degree of pollution can be tolerated if the effluent is discharged into a source of water used only for industrial purposes than into a river from which water is taken for a domestic supply.

Many types of waste liquor from processes in which animal or vegetable products are used as raw materials are best treated by biological methods similar to those used in sewage disposal. Waste water from the milk industry can now be treated satisfactorily by alternating double-filtration. A process for treating waste water from the manufacture of cider has recently been devised. These cider liquors are deficient in nitrogen, and an ammonium salt is therefore added in sufficient quantity to maintain a high enough nitrogen : carbon ratio to support the micro-organisms which bring about the purification.

Many waste liquors require treatment by purely chemical means. For example, the waste waters from the pickling of copper contain free acids and copper salts which have been known to kill all living organisms in a long stretch of river. These are now treated by electrolysis to recover metallic copper and to regenerate free acid, which is re-used. In treating waste waters containing cutting oils from engineering factories, the problem is to devise a suitable method of cracking the emulsion of oil so that it can be removed as a scum.

The Public Health (Drainage of Trade Premises) Act of 1937 allows manufacturers, subject to certain conditions, to discharge waste waters to the municipal sewers for treatment at a sewage disposal works. This is frequently the cheapest and most convenient method of disposal, particularly for small factories, but some types of liquid contain substances which would interfere with the processes carried out at the sewage disposal works. Thus pre-treatment at the factory may be necessary, but sometimes it can be avoided by modifying the manufacturing processes. For instance, some constituents of gas liquors, such as the higher tar acids and thiocyanate, cause difficulties at a sewage disposal works. Tar acids are thought to be responsible for causing an objectionable reddish colour in the sewage effluent. Both thiocyanate and the tar acids are difficult to oxidise in a biological-treatment plant and may therefore cause an increase in the concentration of oxidisable matter in the effluent. These difficulties can be avoided if the hot gases are passed through an electrostatic precipitator to reduce the concentration of the higher tar acids, the concentration of thiocyanate being reduced by excluding air from the gas until a late stage of purification.

In some industries modification of the manufacturing processes has enabled the waste liquors to be re-used in the factory. In Britain a sugar beet factory of average size

handles about 2,000 tons of beet per day. The plant required to treat the waste waters would be as large as that required to handle sewage from a town of at least 200,000 people. When the industry was first introduced to England the waste waters at some factories were passed through lagoons and then discharged to a river. The amount of liquid discharged from a factory of average size would have the same polluting effect as about 1½ million gallons of sewage daily. The general practice at beet sugar factories nowadays is to treat the waste waters by sedimentation either in tanks or lagoons, and then re-use them for transport and washing of the beet and for the extraction of sugar.

When the flax industry was established in Britain during the war the Water Pollution Research Laboratory was asked by the Ministry of Supply to advise on the treatment and disposal of waste waters from retting. The traditional processes of retting, or exposing the straw to moisture, involve soaking bundles of flax for two or three days under anaerobic conditions either in a hole filled with water or in closed rectangular tanks. Tests showed that the mixed waste liquors from retting one ton of flax would be equivalent in polluting effect to about 39,000 gallons of average crude domestic sewage, besides being strongly acid. Treatment to yield an effluent of good quality would have been extremely expensive, but it was considered that continuous treatment by biological methods might render the liquors suitable for recirculation to the retting tank. This involved aerating the tanks by diffused air or running the waste through percolating filters. By the method eventually evolved water is continuously aerated in the retting tank and between rets is pumped to a storage tank. Additional water is added to make up for losses, and the liquor is returned to the retting tank for the next ret. At the end of the season the liquor in the tanks can be disposed of by spraying it over as large an area of land as possible.

The disposal of industrial wastes presents a very serious problem in parts of the Colonies where there are few rivers and available water supplies must be very carefully used. The Water Pollution Laboratory has been able to assist the Colonies by devising efficient methods of re-using the waste liquors from such industries as the production of coffee and sisal in East Africa.

For the experimental treatment or testing of sewage and industrial wastes a small battery of experimental filters has been built at Garston. This is a very simple plant, ordinary drainpipes filled with coke and other suitable materials being used for the experimental filters. The effluent under investigation is stored in a small galvanised iron tank. To overcome the difficulty of regulating the low rate of admission to the filters, the dosing valve consists of a simple plug valve, constructed on the same principle as an ordinary three-way laboratory stop cock, which is electrically operated and rotates once in every four minutes. This system gives satisfactory operation with minimum supervision, whereas the use of a measuring head and orifice would necessitate attention every few minutes to keep the orifice from being choked.

One of the most important and difficult considerations in investigating the pollution problem is the possible effects of industrial and household effluents on fish. Not only have fresh-water streams to be considered, but also the estuaries through which migratory fish such as salmon have to pass on their travels to and from their feeding grounds in the upper reaches of a river. Fishing interests have, of course, played a very prominent part in the campaign to preserve the amenities of British streams and rivers.

The Water Pollution Research Laboratory has been endeavouring to develop basic methods for determining the toxicity of various substances to fish. This is an extremely difficult investigation, since the resistance of different kinds of fish varies considerably, while toxicity is also influenced by such factors as temperature, acidity and the oxygen content of the water. . All these background problems require to be thoroughly cleared up.

The resistance of rainbow trout to cyanide is at present under investigation at Garston. The method adopted is to keep the fish in a constantly flowing stream of well-aerated water into which a measured quantity of cyanide is introduced. The main supply of water is passed through a filter to remove any residual chlorine and thence into a tank maintained at a constant level. From this tank it is discharged through an orifice into a pipe to which the poison is admitted at the desired rate by means of hypodermic syringes operated by a series of valves mounted on a heart-shaped cam. The water and cyanide then pass through a complex system of mixing vessels before being admitted to the test tank.

When the effects of the poison begin to be experienced the fish gradually lose their sense of balance and start swimming sideways or on their backs. If promptly removed from the tank when these symptoms appear they quickly recover and no appreciable lasting effects have been detected.

While these laboratory experiments should yield valuable data on the resistance of fish to poisons, other methods are necessary to determine the effects of toxic substances on the ecology of a stream. Pollution might also affect fish in various indirect ways, such as by destroying their food supplies. It is also necessary, therefore, to determine the effect of pollution on the plants and insects in rivers. In examining this aspect of the problem close collaboration is maintained with the Fresh Water Biological Association, whose laboratories are at Wray Castle near Windermere.

Valuable information has also been gained by detailed surveys of polluted rivers and estuaries. One of the earliest undertakings of the Water Pollution Research Laboratory was to survey the River Tees. Although relatively clean in its upper reaches this river at one point received large quantities of sewage works effluent, and in the estuary the whole of the domestic sewage from Middlesbrough and other towns was discharged without any form of treatment, together with industrial waste waters, particularly from the pickling of steel and the purification of coke-oven gas. For many years the salmon fishery of the Tees, once very valuable, has been declining, and one of the principal objects of the investigation was to determine the relative importance of the various polluting substances in bringing this about.

It was found that very large numbers of salmon and sea trout smolts were killed in attempting to pass seaward through the estuary water. By determining the toxicity to trout of the most toxic constituents, both singly and in admixture, at different temperatures and in water

containing different concentrations of dissolved oxygen, it was concluded that by far the most important cause of fish mortality was the discharge of cyanides in coke-oven effluents. As a result of this survey the harmful effects of pollution on the fish in this river have been greatly reduced.

Another long investigation was made before the war to determine whether changes in the deposition and distribution of mud in the Mersey Estuary were caused by large quantities of untreated sewage discharged from Liverpool and other towns. The knowledge gained from this survey has assisted the Laboratory to devise methods which could be applied in studying other polluted estuaries. A detailed survey of the Thames is at present being undertaken for the Port of London Authority. The Thames is notoriously polluted, and one of the purposes of this investigation is to study the possible effects of pollution on the deposition of mud.

Under the Rivers Board Act the whole of Britain has been divided into areas, a Rivers Board being set up to administer the rivers in each area, with full powers to deal with pollution. This new machinery will not prevent any private person from taking action under the Common Law if aggrieved by pollution.

Due to the efforts of research workers, local authorities and other interested bodies, the standard of river cleanliness in Britain is probably the highest of any industrial country in the world. It is only by continuous attention, however, and by unremitting development and research, that the very marked progress in combating pollution can be maintained.

Pollution of the River Derwent

THE Pride of Derby and Derbyshire Angling Association Limited and the Earl of Harrington, as riparian owners and owners of fishing rights, claimed injunctions and damage for pollution of the River Derwent against British Celanese Limited, Derby Corporation, and the British Electricity Authority (East Midlands Division). The plaintiffs alleged that Derby Corporation had polluted the River Derwent by the discharge of insufficiently treated sewage, and that the British Electricity Authority had polluted it by discharging heated effluents into it.

Mr. Charles Russell, Q.C., appeared for the plaintiffs; Mr. Milner Holland, Q.C., for British Celanese Limited; Sir A. Clark, Q.C., for Derby Corporation; and Mr. H. E. Salt, Q.C., for the British Electricity Authority.

Mr. Russell said that in 1945 the plaintiffs' fishing waters held a very large stock of fish, probably amounting to several millions, and consisting of various types of fish. Some 100,000 fish had been put in the River Derwent by the Trent Fishery Board and the Earl of Harrington Angling Club. Today those waters were devoid of fish life, and dead fish in large numbers had been seen floating in the river on numerous occasions.

The plaintiffs alleged that at a certain time of the year when the rate of flow of the River Derwent was about 100 million gallons a day, British Celanese Limited extracted 54 million gallons of water a day, returning 12 million gallons of effluent, and Derby Corporation introduced nine million gallons of sewage effluent, making a total of 21 million gallons of polluted water in the remaining 46 million gallons of river water.

A Riparian Owner's Rights

Mr. Russell said that a riparian owner was entitled to have the water of his stream brought down to him in its natural state. The escape of injurious matter into water constituted a trespass. Interference with a several fishery was the invasion of a legal right. It was an offence to put offensive matter into rivers under the Rivers Pollution Prevention Act, 1876, and now under the Rivers (Prevention of Pollution) Act, 1951.

Offensive matter put into a stream could not be the subject matter of complaint by lower riparian owners if it did not pollute the water, but if several people did so, and they polluted the water by their combined action, none of them could be heard to say that his particular effluent did not cause the pollution.

Statements for Defendants

Sir Andrew Clark, for Derby Corporation, said that they had pleaded that they did not pollute the river so as to avoid embarrassing their co-defendants. He was now prepared to admit that the river was seriously polluted. He did not admit, however, that the Derby Corporation contributed to the pollution, or that, if they did do so, they did so materially.

The corporation were considering the construction of new sewage works. This project had been held up for several reasons. British Celanese Limited had asked them to dispose of their trade effluent, and at present it was under consideration whether they would be able to agree to that proposal.

Sir Andrew said that there were no regular complaints of pollution by the corporation, only isolated complaints if something had been temporarily blocked. The corporation intended to increase their sewage works for their own satisfaction, but it would require time before it could be done.

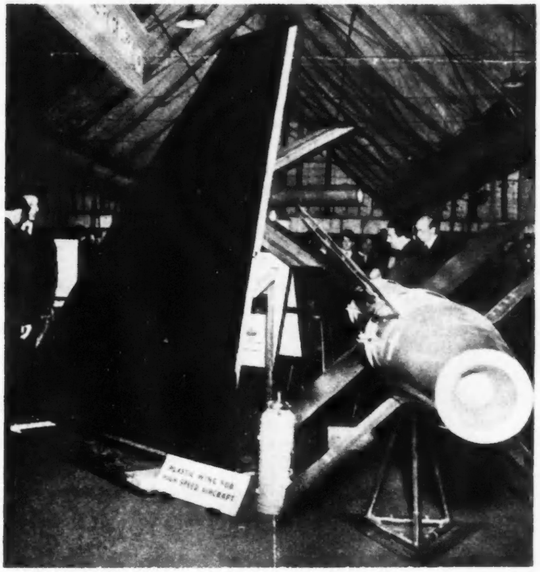
Mr. Justice Harman.—Surely it cannot be right to admit crude sewage into the river?

Sir Andrew Clark.—Yes, that is the whole point of the storm overflow; it is not possible to screen it, or it might cause flooding in houses in Derby.

He said that the storm overflow system was used regularly all over the country. An alternative system would cost several millions, and an injunction against the corporation would have to be suspended for a considerable number of

[*Continued on p. 88*

The Plastic Aeroplane



Not long ago the Ministry of Supply announced the experimental development of a new aircraft-construction technique in which a specially strong plastic, moulded to shape, was used. Structures made by this method could, it was claimed, be manufactured quickly with comparatively simple tools, and plastic aircraft made more cheaply were forecast. This picture, and the explanation below, are reprinted from the 'I.C.I. Magazine'.

THE use of plastics by the aircraft industry is, of course, not new. In general, however, plastics have not been used for the construction of airframes, either because they could not compete with metals in performance or, where their performance was adequate, because their use was not economical owing to fabrication difficulties.

The important properties in a material for the construction of airframes are lightness, strength and stiffness. These properties must be combined; no one can be sacrificed to any of the others. Materials that have high strength/weight and stiffness/weight ratios are therefore required, so that, although light and comparatively thin sections are used in construction, the resistance of these sections to both fracture and bending will be great enough to withstand the stresses that aircraft in flight are subject to.

Laminates in which glass fibre is bonded with polyester resin are not suitable for airframe construction; the structures would have a high strength/weight ratio but would lack the necessary stiffness. Plastic laminates of asbestos bonded with phenolic resin are light and have both the strength and the stiffness required, but were originally thought to offer no advantages over metal because they were difficult to mould. Recently, however, simple, inexpensive techniques for moulding asbestos phenolic laminates have been devised, and aircraft wings made of the material have been tested.

Two methods of moulding have been devised. The first is a vacuum-bag technique similar to that used in moulding 'Nuron' glass cloth laminates. The resin-impregnated asbestos is placed in an open female mould and covered with a thick porous pad. Outside this a rubber bag is placed and then the air between the rubber bag and the asbestos is completely drawn off, creating a vacuum, so that the bag is forced by the atmosphere surrounding it on to the asbestos. The mould is heated, and the combination of heat and atmospheric pressure completes the cure by causing the resin first to soften and flow among the asbestos fibres and then to set.

In the simpler method of moulding the laminates no pressure at all, in the usual sense of the word, is used. Before being placed in the open mould the asbestos felt is soaked in a water-soluble resorcinol resin which locks the fibres in position. The mould is then heated and the heat cures the phenolic resin.

This method of moulding is suitable only for the construction of quite simple components, but its advantage is that it requires only the most simple equipment—wooden formers being suitable when only a few mouldings are to be made. The vacuum-bag technique is more efficient and produces a finished material of superior properties and higher accuracy of contour.

In practice both techniques have been combined in the fairly complex mouldings required for the wings so far tested, the vacuum-bag technique being used for moulding the shell and the open-mould method for the inner structure.

At the recent exhibition held by the Society of British Aircraft Constructors an asbestos-phenolic delta wing was on show. This was of double-skin construction, the outer skin presenting a highly polished continuous surface unbroken by joints or by the heads of fastenings, all of which were hidden in the inner skin. (One of the great advantages that the plastic laminate brings is the easy production of perfectly smooth wing surfaces by the use of double-skin construction methods.)

It seems likely that successful plastic aircraft structures will differ radically from metal ones because, while the stiffness/weight and strength/weight ratios of the laminate are of the same order as those of the better light alloys, their specific gravities differ considerably. A plastic and a metal structure designed to fulfil the same purpose may, therefore, be very different in shape and size.

The designer is thus presented with new problems. It already seems practicable, however, to construct plastic airframes as light as or lighter than their metal equivalents in such a way that the advantages of the new material are fully exploited.

How Eggs Are Laid

WHEN Fabricius, the seventeenth-century Italian anatomist, published his great treatise, *The Formation of the Egg and of the Chick*, he was unable to explain why the egg is always laid broad end first. It seemed to him, as it seems to most people, that if the narrow end emerged first egg-laying would be easier on the hen.

Since then mathematicians have provided an answer: the broad end offers a greater surface area for the egg-laying muscles to work on, thereby reducing the risk of damage both to the egg and to the fowl.

Now, as a result of research on this subject at the Anatomy School, Cambridge, another question has arisen.

Messrs. J. R. G. Bradfield and J. A. F. Fozzard have obtained X-ray photographs of egg-formation in the hen showing that until about two hours before the egg is laid the *pointed* end is directed towards the way out. Then the whole egg is rotated through 180 degrees about the short axis.

Why the egg-shell should not be laid down from the beginning in the position required for expulsion is the new question. How the rotation is accomplished is also a mystery.

The X-ray studies otherwise confirm data on egg-formation in the hen previously built up mainly from the evidence of dissections.

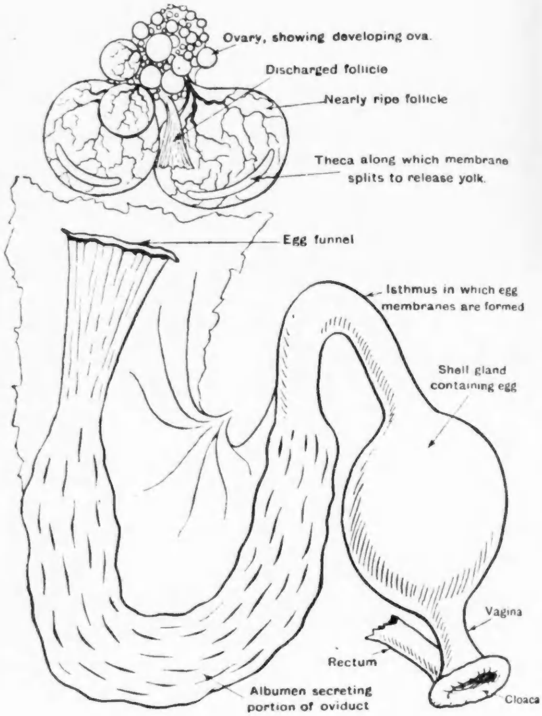
The ovum—what is really the egg proper, containing the germ-spot which after fertilisation becomes the embryo—is set free from the ovary about 30 minutes after the laying of the previous egg. A further half-hour or so is needed for it to get into the single oviduct—a coiled tube about two feet long and divided into four well-defined sections.

Because there is a gap between the ovary and the oviduct each ovum is shed into the body cavity. But it is quickly embraced and finally engulfed by the oviduct's funnel-shaped end, undergoing considerable deformation in the process but rarely bursting, since its membrane, though thin, is capable of withstanding a pressure of 0·06 lb. per square inch.

The ovum remains about three hours in the first section of the oviduct. There, rotating as it passes slowly backwards, it is covered by two coats. The first is a thin mucilaginous layer drawn out at the narrow and the broad ends into two strands called chalazae, which later become twisted and are usually visible in a lightly boiled egg.

The second layer, composed of thick albumen, anchors the chalazae, keeping the ovum moored in the centre of the egg but allowing it to rotate about its long axis. By this arrangement the ovum is able to adopt a position in which the germ-spot is uppermost no matter how the egg may be turned over in the nest. This ensures that the embryo is always as near as possible to the warm body of the incubating hen.

In the second section of the oviduct—the isthmus—two papery shell-membranes are added. These remain separate at the broad end enclosing a space which increases in size during incubation and becomes filled with air drawn in through the porous shell. The chick makes use of this air supply just prior to hatching.



DIAGRAMMATIC SKETCH OF EGG APPARATUS OF FOWL

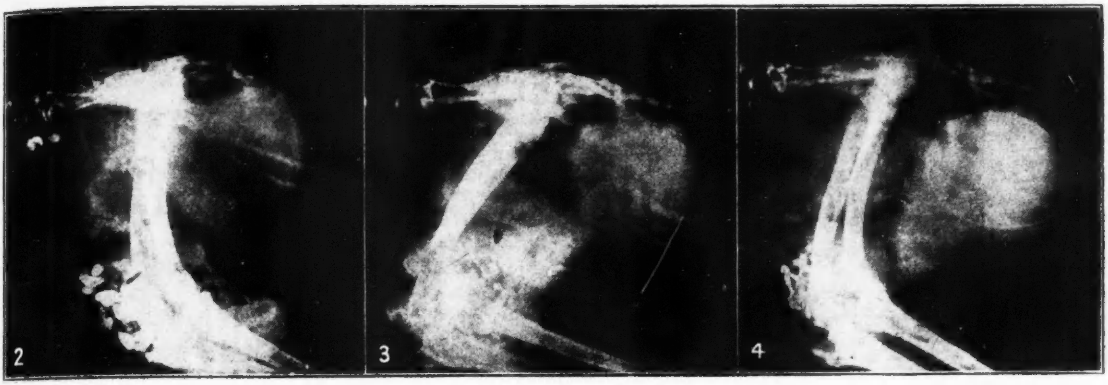
FIG. 1.—The yolk develops from a single cell called the ovum, which is formed from the ovary. The white of the egg, the shell membranes and the shell itself are laid down during the passage of the yolk through the oviduct. The oviduct consists of a muscular tube, lined internally with secretory glands, and is divided into four parts, the *pars magnum* or albumen-secreting portion, the isthmus or shell membrane-secreting portion, the uterus or shell-secreting portion, and the vagina.

Whilst the shell-membranes are forming—a process which takes about an hour—more albumen of a rather watery consistency is secreted by the isthmus lining and diffuses into the egg.

The isthmus expands suddenly to form a globular shell-gland in which the egg remains for a further 20½ hours whilst the chalky shell is laid down and more albumen diffuses in. The shell is put on in three stages. Only the outermost layer—the surface cuticle—contains any pigment.

The whole process from the shedding of the ovum to the laying of the egg takes about 26 hours. One fully formed egg a day is therefore the production limit for a normal hen.

There is no reason why two ova should not pass through



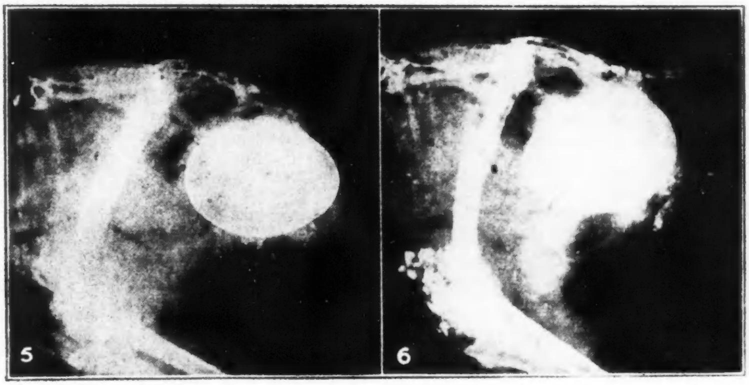


FIG. 2.—The earliest trace of calcium deposition is first visible as a very thin hair-like line about six hours after laying the last egg.

FIG. 3.—At nine hours the density is increased.

FIG. 4.—At 12 hours the density of the shell is distinct, with the pointed end of the egg in advance.

FIG. 5.—At $23\frac{1}{2}$ hours after laying the last egg the pointed end of the new egg is still in advance.

FIG. 6.—Now occurs one of the strangest moments. During the 24th and 25th hours the egg rotates on its vertical short axis in a horizontal plane so that the pointed end is upstream and the blunt end presents to the cloaca.

(*Courtesy "British Medical Journal"*.)

the albumen-secreting tract and isthmus in quick succession. But the second egg would still be held up for the $20\frac{1}{2}$ hours that the first egg has to remain in the shell-gland.

Actually when two ova are present in the oviduct they usually pass into the shell-gland together and are enclosed in a common shell, the result being a double-yolked egg. According to figures given by Curtis this happens in large flocks about once in 530 times, being commonest in birds under eight months of age.

It seems that only occasionally is the presence of two ova in the oviduct due to the fact that they were released simultaneously by the ovary. More often the cause is that the first yolk has been delayed somewhere in the oviduct and the second overtakes it. Occasionally the first ovum is forced back up the oviduct towards the second.

Three-yolked eggs are extremely rare.

Although a diet deficient in calcium results in the formation of soft-shelled or shell-less eggs, these are more often the effect of overfeeding, which seems to reduce the length of time the egg spends in the shell-gland.

These soft eggs, in my opinion, constitute important evidence with regard to the mechanism of normal egg-laying. If really considerable forces are exerted on the egg by the muscles of the shell-gland then one would expect that soft eggs would frequently be burst during the laying process. In my experience this rarely happens.

With a completely shell-less egg there may be enough elasticity in the shell membranes for deformation and recovery of shape to occur. But in the case of the egg with a partly formed shell this explanation does not apply. Anyone who has handled such an egg knows that its thin brittle covering fractures at the slightest touch. Yet rarely is such a shell broken during the laying process and when it is, contact with the ground is usually the cause rather than the constricting action of the muscles.

I do not think much pressure is actually exerted on the egg-shell during laying. The shell-gland appears to turn almost inside out and deposits the egg gently on the nest.

So why the egg emerges broad end first—apart from the fact that in that position it fits more snugly in the shell-gland—is still a mystery to me.

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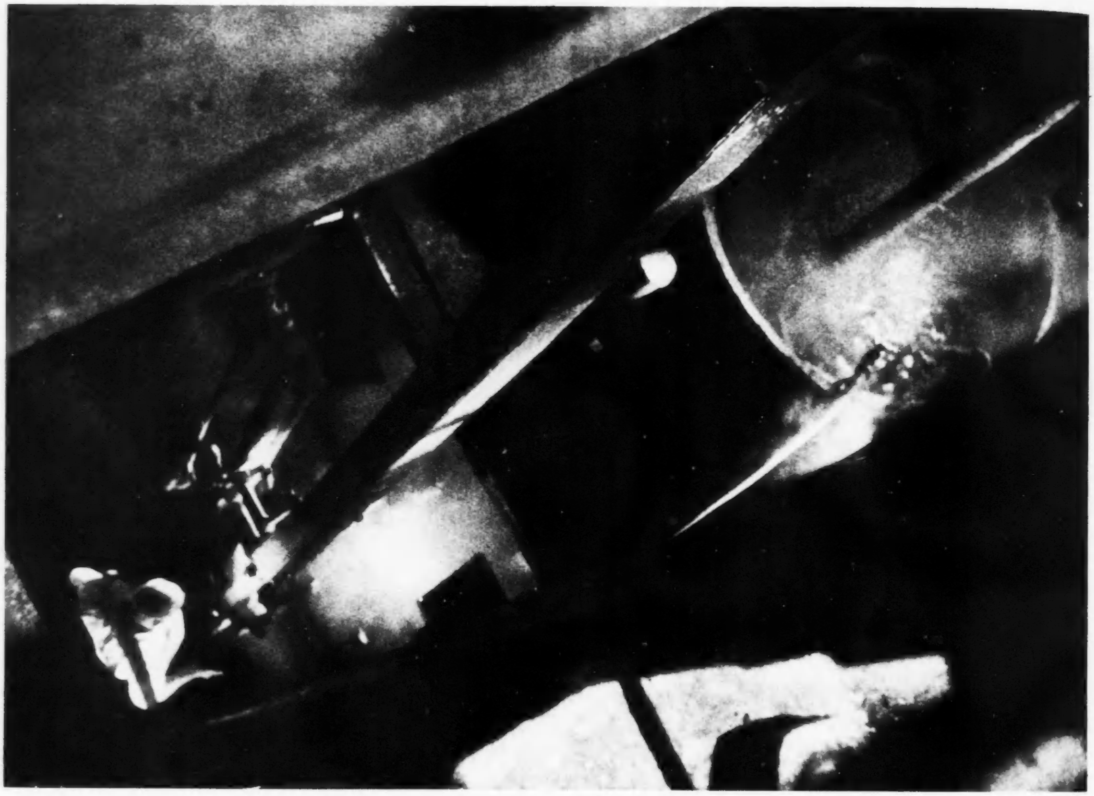


FIG. 1.—The Newcomen Engine, showing the open top of the cylinder and the layer of water sealing the top of the piston. (*This picture and those on p. 98, courtesy 'Shell' Refining and Marketing Co. Ltd.*)

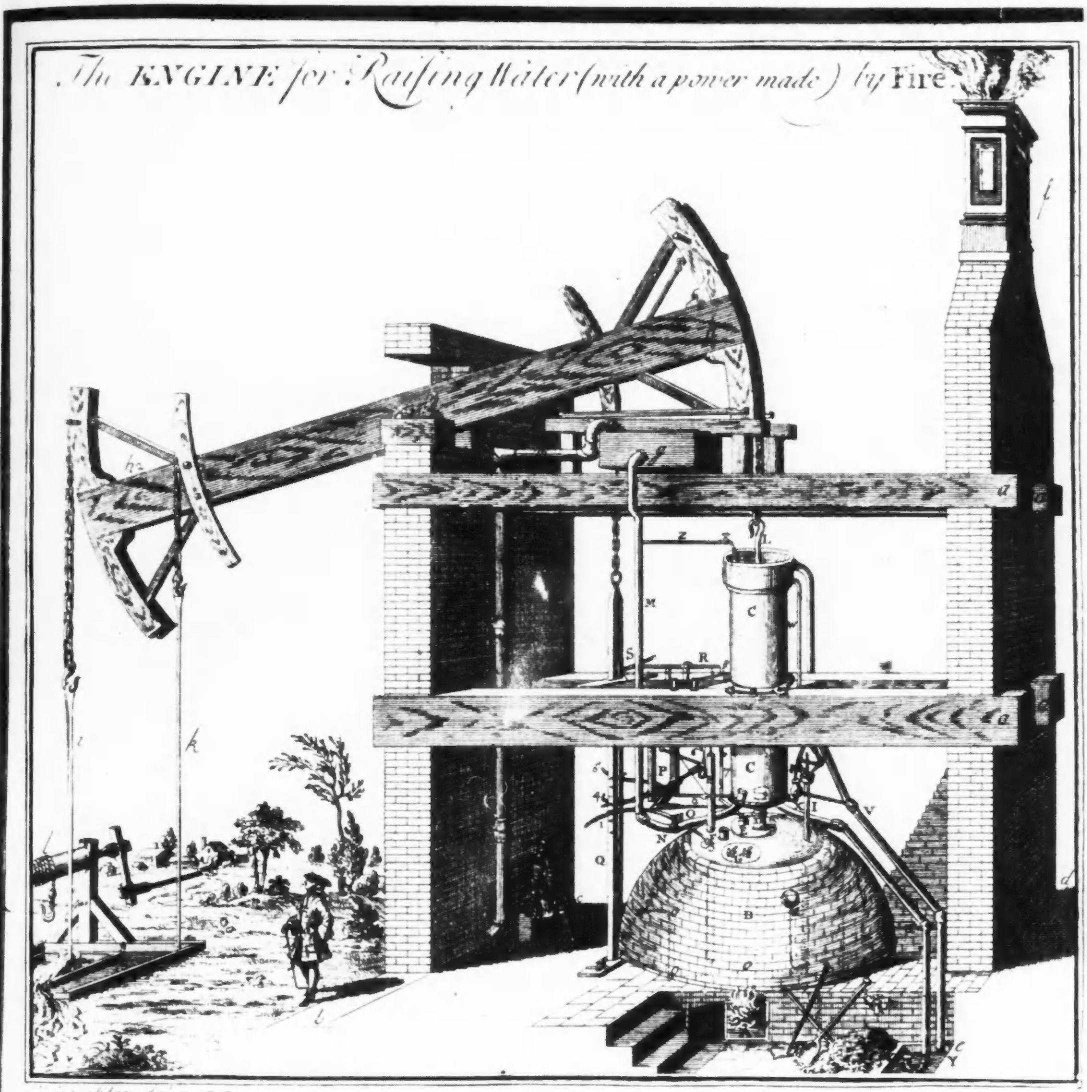
A Working Atmospheric Engine

DENIS SEGALLER

IN October 1951, a very early steam-engine was coaxed into running again after lying idle for seventeen years. She is probably the oldest steam-engine in the world still running today.

One often hears it said that James Watt 'invented' the steam-engine, which is certainly not true. As with many other machines—the motor car, for example—no one man invented the steam-engine; it evolved through the years. Hero, a Greek mathematician, born at Alexandria in the first half of the second century A.D., is believed to have made a toy which drove itself round by steam, and during the Middle Ages many isolated designs and attempts were made to derive power from steam. But the first successful steam-engine in its present-day sense—a machine which obtained useful and continuous power from steam *by means of a piston moving in a cylinder*—was made early in the eighteenth century by a Devonshire ironworker, Thomas Newcomen.

The principle of his engine was simple. It was originally designed to pump water out of waterlogged mines, and the vertical pump-rod extended up out of the mine shaft and was attached at its top end to a huge wooden beam, pivoted at its middle like a seesaw. To the other end of this great beam was attached the vertical piston-rod—or chain, as it was in the first design. The piston, a flat metal disc, was fixed to the lower end of the piston-rod, and slid up and down in the cylinder. The latter had no top, but was open to the atmosphere, and the steam was contained in the space formed by the bottom and round wall of the cylinder and the piston. Immediately below the cylinder was the boiler, with the furnace in turn beneath that. (The general design can be seen from the contemporary engraving reproduced on page 97.) When at rest, the weight of the pump-rod kept its end of the beam downward, so the other end was up, the piston being at the top of its stroke. During running, steam at just over atmospheric pressure was let into the cylinder until it was full. The steam inlet was then shut off, and a jet of cold water was injected into the cylinder. This quickly condensed the steam, causing a partial vacuum under the piston, and the



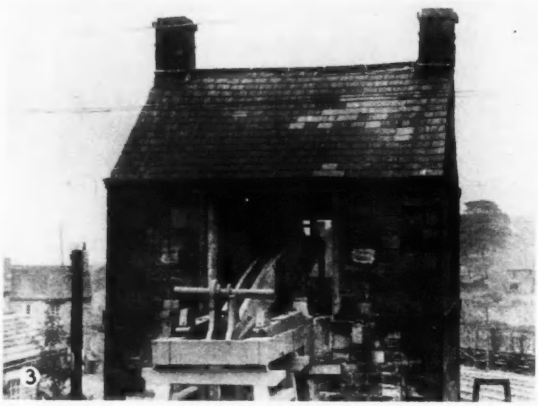
pressure of the atmosphere on the top of the piston pushed it down, so pulling up the pump-rod and pumping up the water from the mine. The cycle was then repeated. It was as simple as that. Since atmospheric pressure did all the work, this type of engine became known as an 'atmospheric' engine.

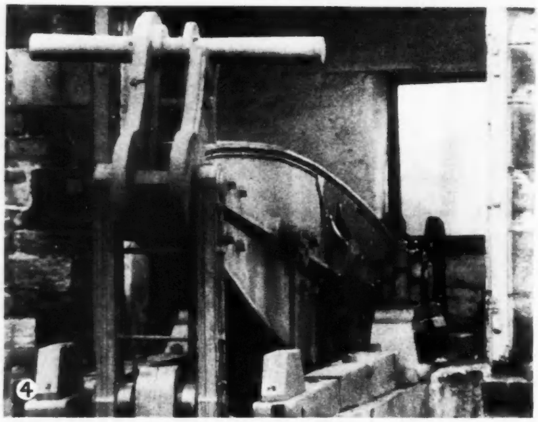
Newcomen's first engine was built in 1712; it was an immediate success. Similar engines were built and used all over the country, mainly for this same job of pumping the mines but also for other industrial work, and even in one case as a bird-scarer!

Later James Watt and other inventors made fundamental changes to the steam-engine which greatly increased its efficiency, but during the greater part of the eighteenth century the atmospheric engine of Newcomen reigned supreme.

One of these engines is still situated at the National Coal Board's north-eastern regional workshops at Elsecar, a mining village near Barnsley in Yorkshire. The exact date of this engine is unknown: 1787 or earlier, certainly not later. She was kept at work until 1934, when she was considered to be of no further use and wasting fuel. But in 1951 the Coal Board, partly at the instigation of the Newcomen Society, decided to try to get her in steam again and run her as a show-piece during Festival year. Unexpected snags were met, and it was not until October that the 164-year-old engine finally moved into action.

One or two things must be said about this particular





engine. She was built at a time when the day of the Newcomen engine was almost over, and in fact she embodies several improvements on the original design. The 24-foot-long beam is not of wood but of cast-iron in two sections, and an amazing job of casting it is, considering when it was made. Also, the ends of the beam are fitted with parallel motion—an invention of James Watt. This is to compensate for the fact that the end of the beam swings in a wide arc of a circle, whilst the positions of pump-rod and piston-rod are fixed in a horizontal sense, i.e. they must always move up and down in *the same* vertical line. The way in which this was taken care of in Newcomen's original design, by "a chain that hangs down from the Arch", can be seen clearly in the contemporary engraving above. There were also other improvements in the furnace and boiler. But in spite of these innovations, this engine was, and remains, an *atmospheric* engine; and she is probably the only one of her kind in the world still running.

But getting her going was not easy. The original pump-rod had had to be sawn through some years back, after the engine ceased working in 1934, and the shaft had to be closed down due to the installation of modern pumping-machinery elsewhere. All that remained was a stump dangling from the beam outside the engine-house (as with most of the early beam pumping-engines, nearly half of the beam protrudes out of the engine-house through a large

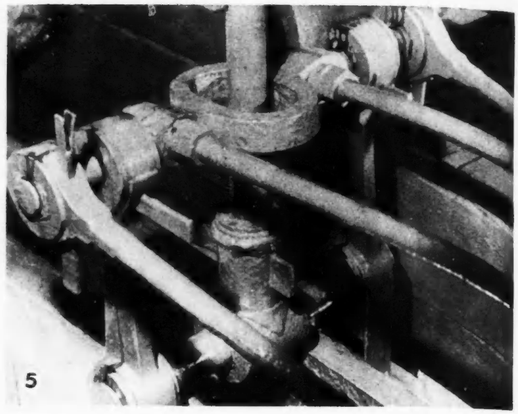


FIG. 3.—The 24-ft. long beam, nearly half of which protudes out of the engine-house.
FIG. 4.—Close-up of the beam which was cast in two sections, showing the 'tupping-piece'.
FIG. 5.—The parallel motion—an invention by James Watt.

square hole in the wall; the pivot is just inside the house). To replace the engine's working load—the weight of the pump-rod and the water it raised—this remaining stump of the pump-rod was modified so that counterweights could be hung on it. Each time the engine was started up, these weights had to be adjusted by trial and error—and plenty of error there was, during the first day or two!

The engine's behaviour was very erratic at first, and she showed a temperament that was almost human. The length of the stroke had to be continually adjusted to keep her going, and the speed fluctuated considerably (normal speed is about six strokes a minute). At times during those first few days the piston appeared to forget when it had reached the bottom of its stroke, and the 'tupping-piece' at the end of the beam came down on to its rests with a smack that set the whole engine-house creaking. Another day she started up well, gradually grew more sluggish and finally stopped altogether. It was found that on that particular day she would only run if the stroke was made shorter. After a lot of trouble the reason was discovered: the 'piston-ring'—in this case a ring of thick rope round the piston—had become unduly swollen with water. The cylinder was not of uniform bore but tapered very slightly towards the bottom, and the rope ring was sticking thus causing the engine to seize up.

After the first few days, however, all these troubles were overcome and the engine ran steadily and evenly. Standing on the top floor of the three-storey engine-house, level with the beam and looking down into the open top of the cylinder, one appreciates the essential difference between the 'atmospheric' engine and all later steam-engines, for one can see the piston. Actually the piston is kept covered with a layer of water a few inches deep, which acts as a seal and helps to keep the inside of the cylinder airtight.

The engine runs normally on steam at only one or two pounds per square inch above atmospheric pressure, compared with the hundreds of pounds pressure in modern engines. In her pumping days she used to raise 50 gallons of water with each stroke, through a height of 130 feet.

Far and Near

Night Sky in March

The Moon.—Full moon occurs on March 11d 18h 14m, U.T., and new moon on March 25d 20h 12m. The following conjunctions with the moon take place:

March			
13d 17h	Saturn in conjunction with the moon	Saturn	7° N.
16d 08h	Mars ,,	Mars	7° N.
24d 02h	Venus ,,	Venus	2° S.
26d 23h	Mercury ,,	Mercury	0·7° S.
27d 05h	Jupiter ,,	Jupiter	6° S.

The Planets.—Mercury is an evening star, setting at 18h 10m, on March 1 and at 19h 45m on March 12 and 31. The planet attains its greatest easterly elongation on March 18 and is stationary on March 26. Venus is a morning star, its times of rising on March 1, 15 and 31, respectively, being 5h 55m, 5h 40m and 5h 15m, stellar magnitude −3·3. The visible portion of the illuminated disk varies between 0·37 and 0·93, which implies that the planet, viewed through a small telescope, presents the appearance of the moon when nearly full. Mars rises at 23h 35m, 22h 55m, and 21h 55m on March 1, 15 and 31, respectively. In the early part of the month it lies a little east of α Librae and at the end of the month is nearly in a line between α and γ Librae, but nearer to α. Jupiter sets early in the evening, at 20h 50m on March 1 and 19h 30m on March 31, or just one hour after sunset, so it will not be a very easy object to observe in the latter case. Saturn rises at 20h 35m, 19h 35m, and 18h 25m, on March 1, 15 and 31, respectively, and can be seen throughout the night lying a little north of θ Virginis during the month.

Vernal equinox takes place on March 20d 16h and about this period the days and nights are nearly of equal length all over the world, the run rising about 6h and setting about 18h, that is, 6 A.M. and 6 P.M. These figures are only approximate and the following figures show that days and nights are not of equal length all over the world at the vernal equinox. On March 20 the run rises at 6h 04m at the equator and at 6h 03m in latitude 60°, so at all latitudes between these the time of sunrise can be taken as 6h 03m, to the nearest minute. But the time of sunset is 18h 11m at the equator and 18h 14m in latitude 60°. We can, therefore, take 18h 12m as good enough for all places between these latitudes, but there is a great discrepancy here as we should expect the sun to set very close to 18h, that is, 6 P.M. The explanation is that the length of the morning exceeds that of the afternoon by twice the 'equation of time', and as the equation of time is −7m 40s on March 20, this implies that on this date the afternoon will be longer than the morning by 15m 20s. If readers will check the lengths of morning—that is from sunrise till noon—and of the afternoon—from noon till sunset—they will see that the results will practically agree with the 15m 20s found above. An explanation of the 'equation of time' is too long to deal with in this article but will be explained later. The subject has been introduced here because many people are puzzled by the apparent discrepancy in the times of sunrise and sunset.

I. G. Farben Central Laboratory Index

KEEN interest has been displayed in the technical information about chemical products marketed under trade names in Europe and America which is available at the D.S.I.R. Technical Information and Documents Unit, Lacon House, Theobalds Road, W.C.1. The index can be inspected by appointment and no charge is made for inspection. Photo copies of entries may be ordered and purchased.

The information is contained in 29 reels of microfilm and is a photographic facsimile of the I. G. Farben Central Laboratory Index. The index appears to have been compiled between the years 1933 and 1943, although a few additional notes are dated 1946, and it comprises more than 57,000 cards. The information is given in alphabetical order under trade names, and includes the chemical name of each product or its analysis, and its constitution and application. In addition information about patents and literature reference is given.

Most of the entries refer to dye-stuffs, but the index also covers resins, plastics, detergents, wetting agents, waterproofing and emulsifying agents, textile assistants, rubber accelerators, cellulose esters, synthetic rubber, oil additives, tannins, insecticides, solvents, pharmaceutical products and other commodities.

Robot Pilot for Jet Fighters

AN American inventor has been awarded the Collier Aviation Trophy for developing and producing an automatic pilot that can be used in jet planes. The bronze trophy was presented recently to William P. Lear by President Truman, in a ceremony at the White House. The award is made annually for "the greatest achievement in aviation in America, the value of which has been demonstrated by actual use during the previous year".

Mr. Lear's invention, the F-5 automatic pilot and automatic approach control-coupler system, is designed to perform many of the flying duties of the human pilot. It consists of a series of gyroscopes and electrical circuits that enable jet planes to take off and land safely in bad weather or under conditions of poor visibility. The approach-coupler accessory helps to guide the plane to the runway even when the pilot cannot see it. The device also enables the pilot to keep his plane in level flight, or to make quick turns, dives, or climbing manœuvres in any kind of weather. The new invention weighs 36 lb., and occupies about one cubic foot. It is the first automatic pilot that can be used in fast, highly manœuvreable jet planes, and it is being installed in most of America's latest jet fighter planes.

Professor A. R. Todd

THE appointment of Professor A. R. Todd, Professor of Organic Chemistry at Cambridge, as chairman of the Government's Advisory Council on Scientific Policy has recently been announced. Professor Todd, who was educated at Glasgow, Frankfurt and Oxford, married the daughter of Sir Henry Dale, O.M., F.R.S.; Mrs. Todd is also a scientist. Professor Todd is already a member of the Advisory Council on Scientific Policy and succeeds Sir Henry Tizard, F.R.S. as Chairman this month. The post is part-time and unpaid.

Faraday Medal

THE Council of the Institution has made the thirtieth award of the Faraday Medal to Professor E. O. Lawrence, Professor of Physics at California University, for distinguished work in the field of nuclear physics. Professor Lawrence was awarded the Nobel Prize for physics in 1939 for his work in conceiving and building the first cyclotron which he used to study the transmutation of elements and artificial radioactivity.

Laboratory Animals Bureau

ON the fifteenth day of each month the Laboratory Animals Bureau, Holly Hill, Hampstead, London, N.W.3, is issuing an "Availability List" indicating what laboratory animals are available and the source of supply. It is divided into three sections: guinea-pigs, mice and rabbits. Users who may have a surplus of any species are asked to notify the Bureau so that the information can be published in the availability list.

Biochemistry and the Meat Industry

AMOUR and Company have announced that a substantial grant-in-aid has been made to Dr. Albert Szent Gyorgyi, Hungarian biochemist and Nobel prizewinner in 1937, for research on the chemistry of muscle.

Dr. Szent Gyorgyi will work on the fundamentals of muscle chemistry, physiology and function.

Practical application of fundamental knowledge which it is hoped will eventually emerge from his work, may help solve many problems of the meat-packing industry; the mystery of 'dark cutters', for instance. These are beef animals which look like any others but which, when processed, yield meat which is so dark it must be sold at a discount, though it is as wholesome as the desirable cherry-red beef.

Why one good-looking cut of beef out of hundreds will cook tough or flavourless, why one of hundreds of pieces of ham or bacon will soak up too much salt, what sugar used in curing does to meat, the chemical effect of heat on meat in the curing process, why some meats will not bind properly in sausage, the effect of freezing on meats—all these are chemical mysteries of the industry. Their solution would contribute to greater efficiency and stability in meat processing.

The Bookshelf

Principles of Lighting. By W. R. Stevens. (London, Constable, 1952, 482 pp., 34*s*.)

THE stated purpose of this book is to describe the principles underlying different types of lighting installation and to exemplify them by current practice. If the book achieved just this it would be hardly more than a technician's handbook full of formulae and data about reflectors and wattage and the like. As such it would be useful but hardly noteworthy here. Actually, very much more is achieved.

The first four chapters are on light and units of measurement, the process of seeing, colour and photometry. The author says that these chapters are compressed. This may be so; nevertheless the amount of fundamental information given in them is astonishing. The physiology of vision, the distribution of light from an extended source, the C.I.E. system of colour specification, and the use of visual and photoelectric photometers are only five of the sixty topics dealt with in these four chapters. The remaining thirteen chapters of the book have a similarly broad scope. The result of all this is that the book is as far removed from the technician's handbook as a Shakespeare play from a mere list of characters and scenes. Mr. Stevens's book is, in short, thorough and comprehensive.

This might suggest that he is wordy. Far from it. The very first sentence of the text reads: "Light is that form of energy which stimulates the eyes to sight." This forthright statement sets the key for the whole book right up to the final factual sentence: "By daylight the eye illumination required to observe a small light source is about 1000 times as great as the night-time value." There is nowhere a sentence that does not advance the exposition; there is hardly a page without an item that is new even to a lighting engineer.

The bulk of the book is given up to the practical side of the subject. There are chapters on the basis of installation design, industrial lighting, lighting for road traffic, for cinema studios and stage, and the lighting of airports. Even artificial light for games finds a place. Each chapter has a bibliography and a list of references. There are nine appendices, one being a glossary of terms. The information is thoroughly up to date—the author is to be forgiven for using 'brightness' instead of 'luminance' in view of the fact that most illumination engineers stick to the older word; he anticipates criticism by adding a footnote on the matter. The speed of light given is actually that found from Essen's recent work. The author steers his way successfully among the many different terms that bedevil the discussion of illumination—the stilb, apostilb, blondel, lambert and even of all things, the nit. (All these words are used for units of luminance.) The unit of luminous intensity used by Mr. Stevens is the candela, a word that has hardly found its way into text-books yet.

There are nice touches of a non-technical sort that stamp the author as a man of modesty and yet of verbal skill. At the beginning he quotes Montaigne: "I have only made a nosegay of culled flowers, and have brought nothing of my own but the thread that ties them together." The author's own observation in his preface finds a sympathetic response in the present reviewer: "Much of what we do in lighting we do because we did." On page 143 he dismisses those unpractical opinionaters who insist on discussing what would happen with a point source of light in these words: "When the area is zero the brightness is infinite—as are the arguments that the idea can lead to."

This book is another feather in the G.E.C. cap—Mr. Stevens is at the research laboratory at Wembley. It is well illustrated and excellently produced. There seems no reason why it should not become the standard text on the subject both for instruction and reference.

C. L. BOLTZ.

The British Amphibians and Reptiles. By Malcolm Smith. (London, Collins, 1951, 318 pp., 21*s*.)

THIS book fully justifies the editors' of the New Naturalist series claim that it fills an obvious gap in the literature on British natural history. Their belief that "it will be the standard work on the subject for a generation or more" will receive confirmation from every herpetologist who, more critical than the general reader, will want to digest its contents to the full.

The author's own description of his book—"an account of the life histories, habits and behaviour of the British amphibia and reptiles . . . a record of our knowledge" is wisely joined with the rider that it is also "an exposure of our ignorance". Such ignorance may be largely due to the attitude adopted by naturalists in the past. First, there are few species to study within the group; the list of fourteen is pitifully small, and in consequence has been sadly neglected. Secondly, there has always been an extraordinary antipathy towards these inoffensive creatures. Even the great Linnaeus opens his description of his "Classis III Amphibia" with the slanderous words, "These foul and loathsome animals . . .", a sentiment which one often hears expressed today (although it is in no way justified) by many naturalists who ought to know better. As for the general public, in their minds the stigma on these "loathsome creatures" is kept alive by frequently repeated mis-statements, for which the popular Press is not entirely blameless. A champion like W. H. Hudson is needed, who can tell the truth in so far as it is known as well as raise a sturdy arm to check the falling stick or crushing heel which all too frequently destroys the lower reptile.

Malcolm Smith's book sets another milestone in British herpetological literature, with a lifetime experience to back his statements. It will spur the herpetologist to greater efforts, and the last chapter on unsolved problems in herpetology is especially stimulating.

As for the general reader, he will find many of the peculiar habits of these creatures are explained to him; but will he be prepared to take in the more technical matter which, it might be argued, has no place in a popular work? Perhaps this herpetological detail, some of it new, could have been balanced with a further chapter or two of more readable matter. In particular, some account of the many strange beliefs, legends and superstitions about these creatures would make delightful reading. These stories, many of which are as old as the country itself, and tightly woven into the pattern of British life, more often than not have their origin in a "truth which is stranger than fiction".

A. G. L.

A Picture Book of Ancient British Art. By Stuart Piggott and Glyn E. Daniel. (London, Cambridge University Press, 27 pp. and 73 plates, 12*s*. 6*d*.)

THIS volume is more or less entirely a picture book. It contains 73 beautiful photographs of the best examples of early British craftsmanship, mainly covering the period from Neolithic times (*c*. 2000 B.C.) to the Roman conquest. It will appeal to the lover of artistic achievement rather than to the scientist, who would like to know more about the technology behind the various articles illustrated. The text is very brief, being in the main an explanatory catalogue of the illustrations.

Our knowledge of the earliest art is necessarily limited to those things which are made of materials that preserve well—for example, stone, pottery, iron, bronze and gold. Woodwork is occasionally preserved, but paint work rarely survives. Britain lacks examples of cave paintings such as are found in France and Spain, and examples of art from the Upper Palaeolithic and Mesolithic, though plentiful elsewhere in Europe, are also extremely rare. The most ancient specimen given in the book is an engraving on bone from Upper Palaeolithic times, which is crude in design and cannot claim any real artistic merit. The same applies to the wooden figures, whose only claim to attention is their rarity.

As would apply to an anthology of poetry, the compiler of a book of ancient art cannot hope to satisfy all tastes. This reviewer would have liked to have seen included a photograph of a flint hand-axe (such articles are outstanding for superb workmanship) as representing a much earlier period. It can, however, be claimed that most of the examples chosen are really beautiful by modern standards, with the Birdlip mirror and the exquisite gold neck ornament from County Clare as the *pièces de résistance*.

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